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PART I

**Bioventing Pilot Test Work Plan for
Areas H and K, and Site 2
Hickam AFB, Hawaii**

PART II

**Draft Interim Pilot Test Results Report for
Areas H and K, and Site 2
Hickam AFB, Hawaii**

Prepared For

**Air Force Center for Environmental Excellence
Brooks AFB, Texas**

and

**15th Civil Engineering Squadron/DEV
Hickam AFB, Hawaii**

ES

Engineering-Science, Inc.

August 1993

1700 BROADWAY, SUITE 900
DENVER, COLORADO 80290

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PART I
BIOVENTING PILOT TEST WORK PLAN FOR
AREAS H AND K, AND SITE 2
HICKAM AFB, HAWAII

Prepared for:

Air Force Center for Environmental Excellence
Brooks AFB, Texas

and

15 CES/DEV
Hickam AFB, Hawaii

by:

Engineering-Science, Inc.
1700 Broadway, Suite 900
Denver, Colorado 80290

November 1992

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PART I

BIOVENTING PILOT TEST WORK PLAN FOR AREAS H AND K, AND SITE 2 HICKAM AFB, HAWAII

1.0 INTRODUCTION

This work plan presents the scope of multiple bioventing pilot tests for *in situ* treatment of fuel-contaminated soils at Area H and Area K on Hickam Air Force Base (AFB), Hawaii and Site 2 at the Waikalaua Fuel Storage Annex. At this time, Site 2 is an alternate site and will only be included in the testing program if additional funds become available. The proposed pilot tests will be performed by Engineering-Science, Inc. (ES). The three primary objectives of the proposed pilot tests are: 1) to assess the potential for supplying oxygen throughout the contaminated soil interval, 2) to determine the rate at which indigenous microorganisms will degrade fuel when stimulated by oxygen-rich soil gas, and 3) to evaluate the potential for sustaining these rates of biodegradation until fuel contamination is remediated to concentrations below regulatory standards.

The pilot test will be conducted in two phases. An air injection vent well (VW) and monitoring points (MPs) will be installed at each site during site investigation activities in conjunction with the ES-Honolulu office. The initial test phase will also include an *in situ* respiration test and an air permeability test, expected to take approximately 2 weeks. During the second phase, a small, single injection well bioventing system will be installed at each site and monitored over a 1-year period.

If bioventing proves to be an effective means of remediating contaminated soils at these sites, pilot test data may be used to design a full-scale remediation system and to estimate the time required for remediating soils to regulatory standards. An added benefit expected from the pilot testing at Area H, Area K, and Site 2 is that a significant amount of the fuel contamination should be biodegraded during the 1-year pilot test.

Additional background information on the development and recent success of the bioventing technology is found in the document entitled *Test Plan and Technical Protocol For A Field Treatability Test For Bioventing*. (Hinchee et al., 1992). This protocol document will serve as the primary reference for pilot test VW and MP designs and detailed test objectives and procedures.

2.0 SITE DESCRIPTION

2.1 Area H

2.1.1 Site Location and History

Area H is located northeast of the Base Exchange complex and is roughly bounded by Fox Boulevard, Vandenberg Boulevard, H Street, and Hanger Avenue

(Figure 2.1). Based on investigations conducted by Groundwater Technology, Inc. (GTI), a very large plume of fuel exists in groundwater beneath the site, possibly caused by long-term fuel leaks from several pipelines. Portions of the plume were determined to have over 6 feet of apparent free product (GTI, 1985). Area H is only one portion of the total fuel-contaminated area which extends beneath approximately 40 acres of the base.

2.1.2 Site Geology

Because the bioventing technology is applied to the unsaturated soils, this section will primarily address soils above the aquifer. Soils at this site consist of a 5-foot thick surficial layer of sandy silt topsoil underlain by weathered grey volcanic tuff extending to a depth of at least 30 feet. Groundwater is encountered at a depth of approximately 15 feet below ground surface (bgs) within the volcanic tuff. Local watering (irrigation) and tidal fluctuations combine to influence groundwater levels such that the groundwater flow direction is undetermined. Local mounding and subsequent radial water flow is present due to landscape irrigation (GTI, 1985).

2.1.3 Site Contaminants

A large, fuel-contaminated plume is known to exist within Area H soil. Measurements of free product on the groundwater by GTI (1985) indicated that the thickest interval of fuel residuals was located in the vicinity of monitoring well GT-H9. Fuel residuals were observed in soil borings at and several feet above the water table. The fuel contamination within the plume was determined to be a mixture of 88 percent aviation fuel (80/87 octane) and 12 percent heavier hydrocarbons in the kerosene range (GTI, 1985).

2.2 Area K

2.2.1 Site Location and History

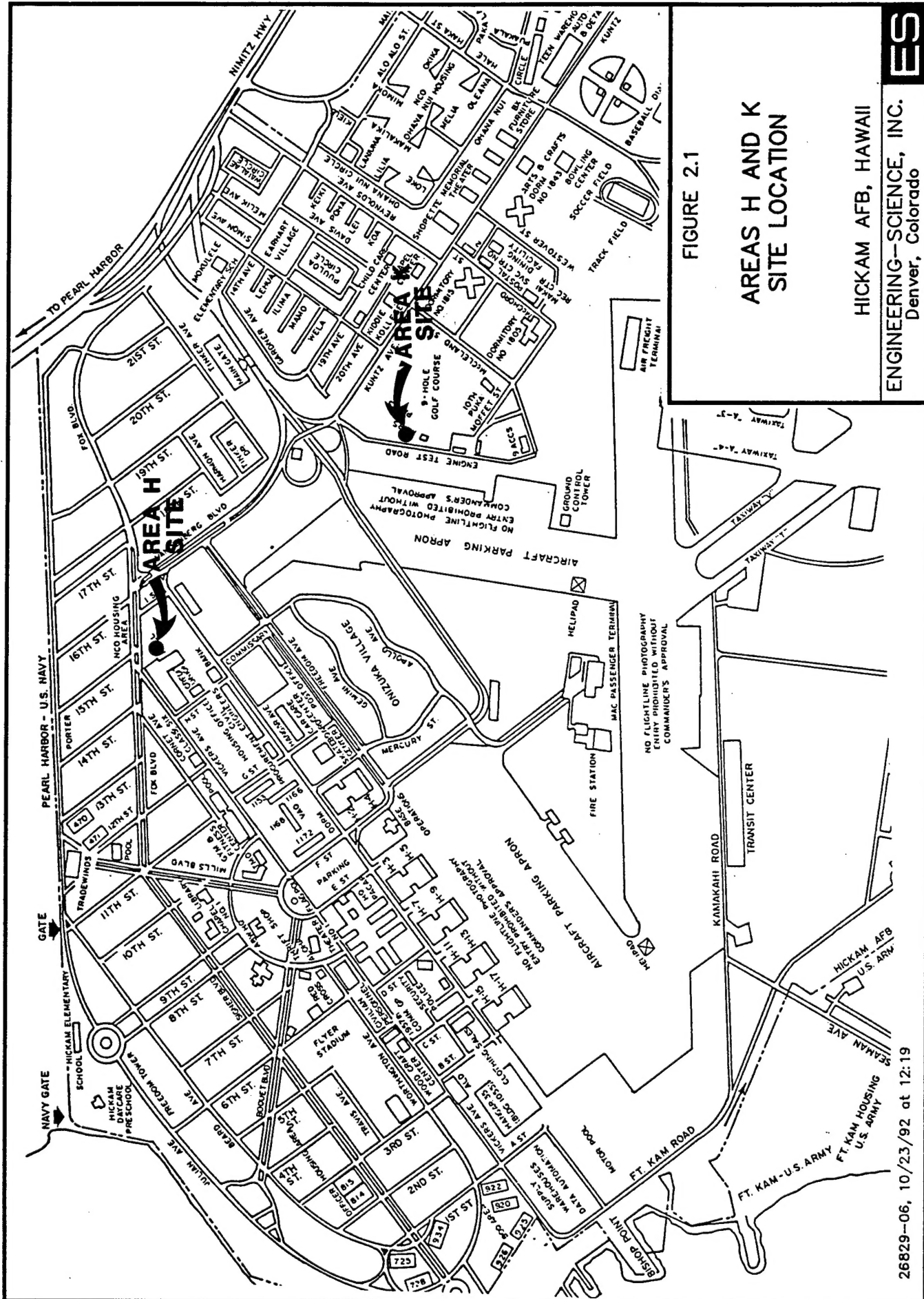
Area K is located on the western edge of the nine-hole golf course adjacent to Engine Test Road (Figure 2.1). A large free product plume exists under the site, possibly caused by long-term fuel leaks from a pipeline located west of Engine Test Road.

2.2.2 Site Geology

Soils at this site consist of sandy silt topsoil overlying coral sand with coral fragments. Groundwater is encountered at a depth of approximately 7 feet bgs.

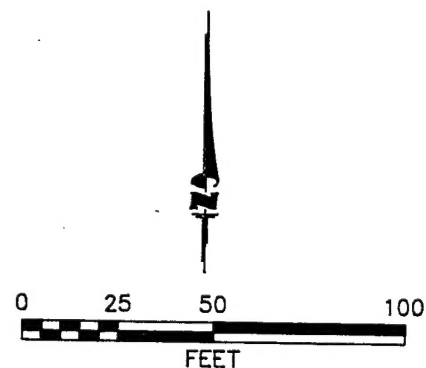
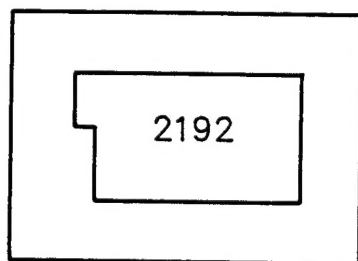
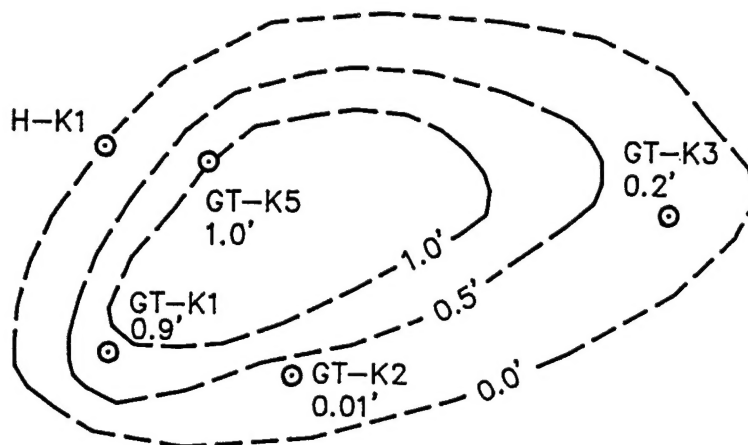
2.2.3 Site Contaminants

A large contaminated plume is known to exist within Area K soils. Measurements of free product floating on groundwater by GTI in 1985 indicated that the thickest interval of fuel residuals was located in the vicinity of GT-K1. Figure 2.2 shows the estimated free product thickness contour as determined by GTI. Fuel residuals were observed in soil borings at and several feet above the water table. The fuel contamination within the plume was determined to be a mixture of 54 percent JP-4 jet fuel and 46 percent heavier hydrocarbons. The





GT-K4

ENGINE TEST ROAD



LEGEND

- H-K1  MONITORING WELL (HIROTA)
- GT-K1  MONITORING WELL (GROUNDWATER TECH)
- — — — — PRODUCT THICKNESS CONTOUR

SOURCE: GROUNDWATER TECHNOLOGY, 1985

FIGURE 2.2

AREA K
FREE PRODUCT PLUME

HICKAM AFB, HAWAII

ENGINEERING-SCIENCE, INC.
Denver, Colorado

ES

presence of the heavier hydrocarbons may be due to volatilization of the lighter hydrocarbons within the JP-4 during natural degradation (GTI, 1985).

2.3 Site 2

2.3.1 Site Location and History

Site 2, Waikalaua Fuel Storage Annex, is located on the Schofield Plateau west of Kamehameha Highway (Figure 2.3). This fuel storage annex consists of nine underground storage tanks (USTs) used to store various fuels since 1943. Since 1971, only JP-4 and JP-8 have been stored at the site.

Suspected types of waste materials disposed of at Site 2 include solvents, fuel tank sludges, and waste from the petroleum, oils, and lubricants (POL) pipeline. Water that collected in the USTs was drained into two cesspools, creating significant soil contamination. Petroleum hydrocarbons and lead have been detected in soil borings near these cesspools.

2.3.2 Site Geology

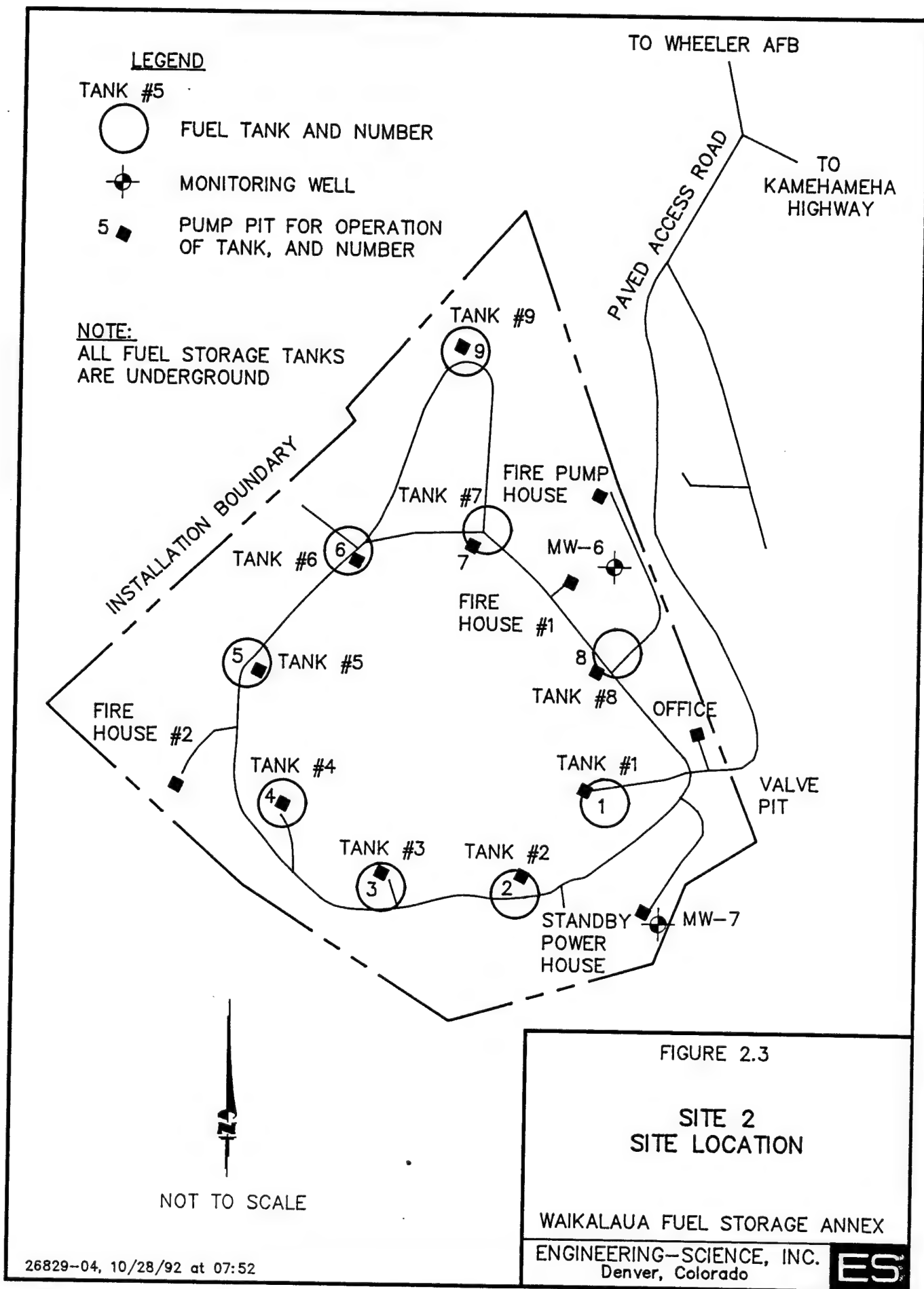
Soils at this site consist of fill material, possible alluvial deposits, and weathered basalt. Soil boring B-2 revealed dark reddish brown silt to about 15 to 20 feet bgs, underlain by saprolite, a highly weathered and fractured basalt. At boring MW-6, dark gray basalt was encountered at from approximately 110 feet to the total explored depth of 155 feet. Groundwater was not encountered at MW-6. The water table may be as far as 500 feet bgs at this location [Harding Lawson Associates (HLA), 1988].

2.3.3 Site Contaminants

Significant concentrations of contaminants at Site 2 were detected in soil samples from depths greater than 25 feet near two cesspools used for waste water disposal. This depth corresponds with the bottom of the concrete cesspools. The highest contamination concentrations detected in B-2/MW-6 at varying depths include lead at 24.6 milligrams per kilogram (mg/kg), total recoverable petroleum hydrocarbons (TRPH) at 3,980 mg/kg, chlorobenzene at 5.1 mg/kg, ethylbenzene at 57 mg/kg, 1,1,2,2-tetrachloroethane at 7.5 mg/kg, m-xylene at 43 mg/kg, o- and/or p-xylene at 49 mg/kg, and toluene at 4.4 mg/kg. Contamination is known to extend to a depth of at least 88 feet at this location (HLA, 1988).

3.0 PILOT TEST ACTIVITIES

This section describes the work that will be performed by ES at Area H, Area K, and Site 2. Activities that will be performed include siting and construction of a central air-injection VW and three vapor monitoring locations, an *in situ* respiration test, an air permeability test, and the installation of a long-term bioventing pilot test system at each site. Soil and soil gas sampling procedures and the blower configuration that will be used to inject air (oxygen) into contaminated soils through the VW also are discussed in this section. Pilot test activities will be confined to unsaturated soils. No dewatering or ground water treatment will take place during the pilot tests. Existing monitoring wells will not be used as primary air injection



wells. However, monitoring wells which have a portion of their screened interval above the water table may be used as vapor MPs or to measure the composition of background soil gas.

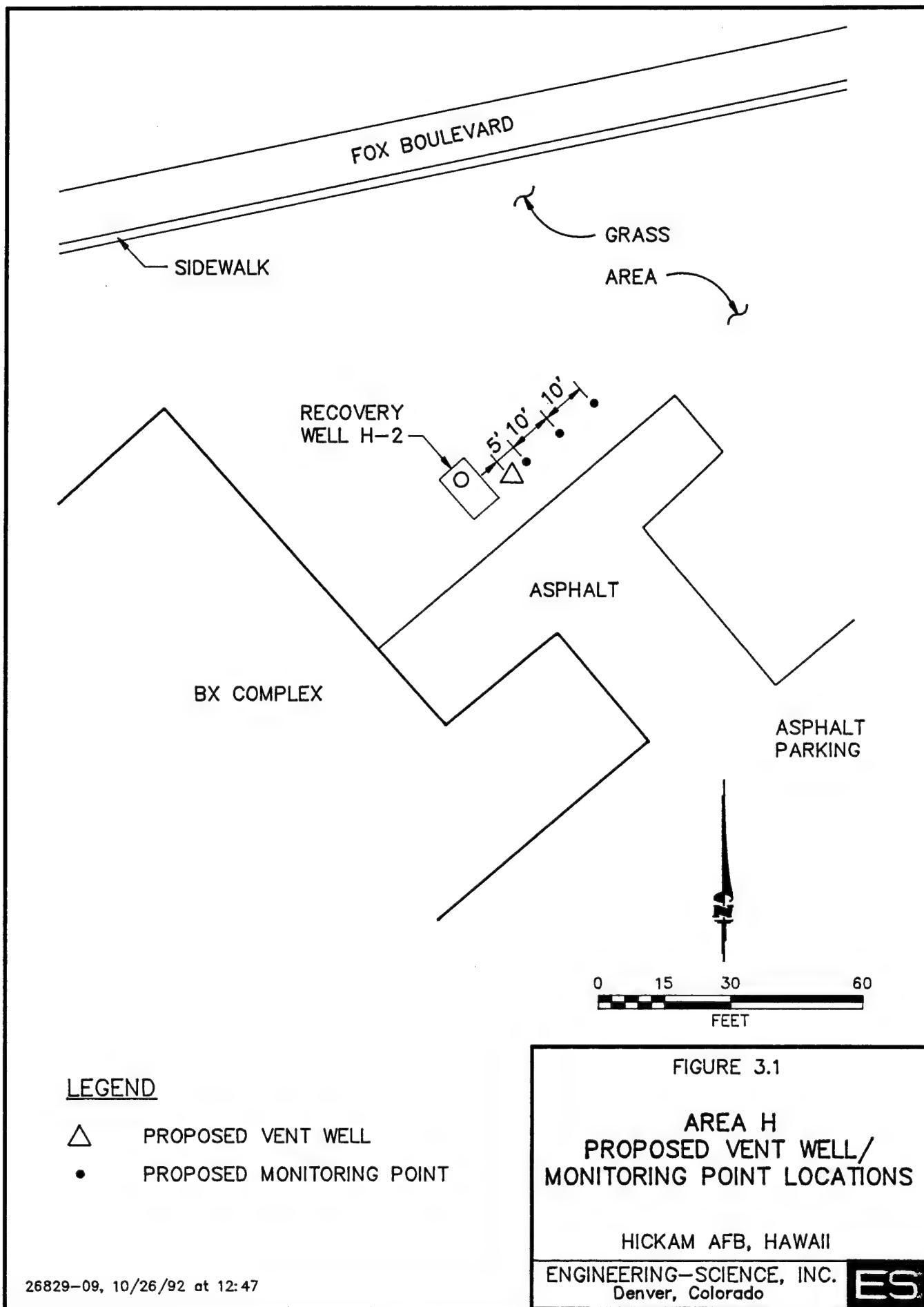
3.1 Area H

A general description of criteria for siting a central VW and vapor MPs are included in the protocol document. Figure 3.1 illustrates the proposed locations of the central VW and MPs at this site. The final locations of these wells may vary slightly from the proposed locations if significant fuel contamination is not observed in the boring for the central VW. Based on site investigation data, the central VW should be located near free product recovery well H-2, which is located in an area which has recently had between 2 and 3 feet of floating free product. Soils in this area are expected to be oxygen depleted (<2%) due to high hydrocarbon levels, and increased biological activity should be stimulated by oxygen-rich soil gas ventilation during pilot test operations.

Due to the relatively shallow depth of contamination at this site, and the experience that ES has had with this soil type, the potential radius of venting influence around the central air injection well is expected to be approximately 25 feet. Three vapor MPs will be located within a 25-foot linear distance of the central VW (Figure 3.1). A fourth vapor MP, to be located upgradient of the site, will be used to measure background levels of oxygen and carbon dioxide and to determine if natural carbon sources are contributing to oxygen uptake during the *in situ* respiration test.

The VW will be located approximately 3 feet east of the recovery well enclosure. The VW will be constructed of 4-inch inside diameter (ID) Schedule 40 polyvinyl chloride (PVC), with a 10-foot interval of 0.04-inch slotted screen set at 5 to 15 feet bgs. Flush-threaded PVC casing and screen with no organic solvents or glues will be used. The filter pack will be clean, well rounded silica sand with a 6-9 grain size and will be placed in the annular space of the screened interval. A 4-foot layer of bentonite will be placed directly over the filter pack. The first 6 inches of bentonite will consist of bentonite pellets hydrated in place with potable water. This layer of pellets will prevent the addition of bentonite slurry from saturating the filter pack. The remaining 42 inches of bentonite will be fully hydrated and mixed aboveground, and the slurry will be tremied into the annular space to produce an air-tight seal above the screened interval. A complete surface seal is necessary in order to prevent injected air from short circuiting to the surface during the bioventing test. Figure 3.2 illustrates the proposed VW construction for this site.

A typical multi-depth vapor MP installation design for this site is shown in Figure 3.3. Soil gas oxygen and carbon dioxide concentrations will be monitored at a depth intervals of 6 feet, 10 feet and 13 feet at each location. Multi-depth monitoring will confirm that the entire soil profile is receiving oxygen, and be used to measure fuel biodegradation rates at each depth. The spaces between monitoring intervals will be sealed with bentonite to isolate the intervals. As with the central VW, several inches of bentonite pellets will be used to shield the filter pack from rapid



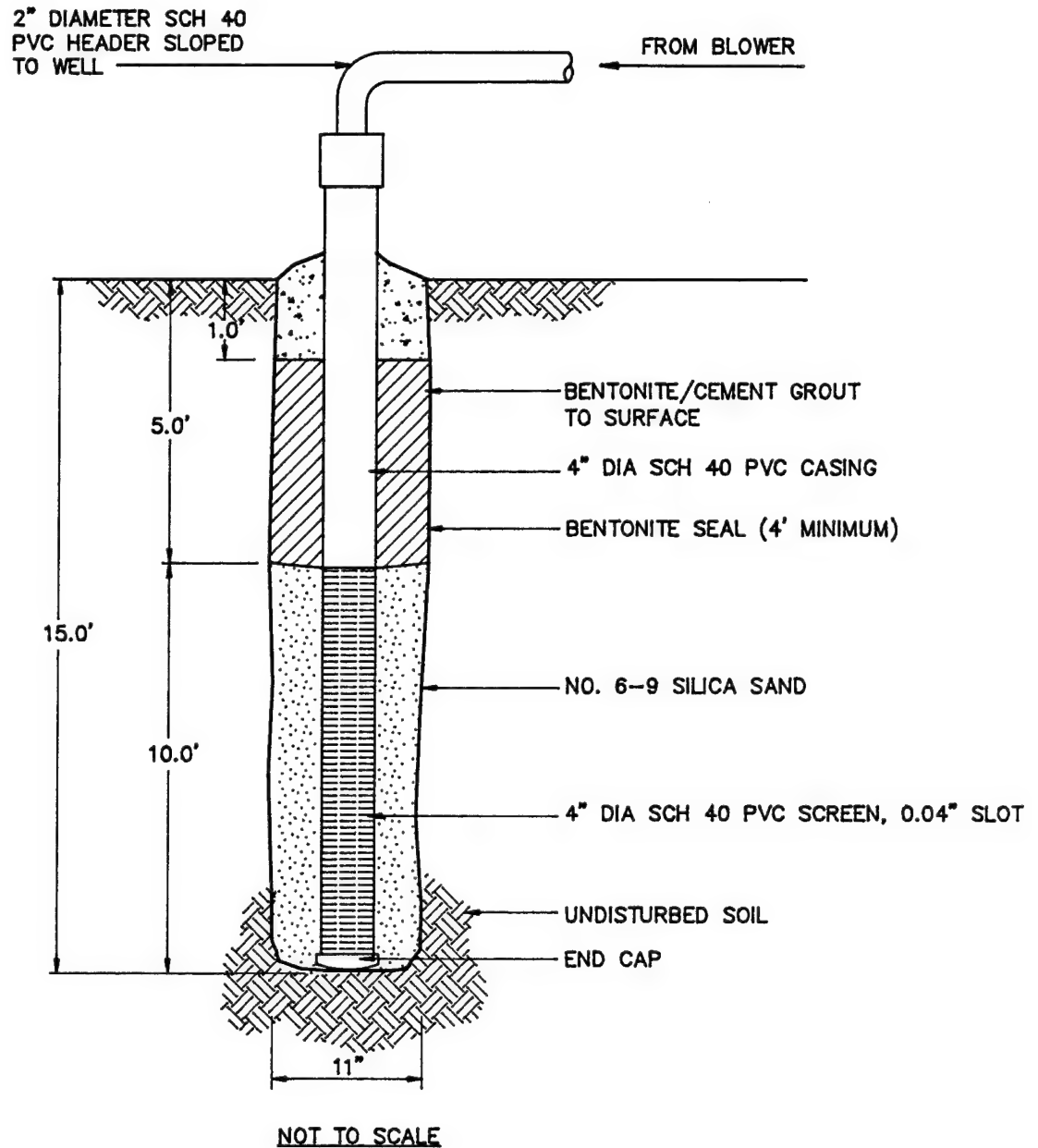


FIGURE 3.2
AREA H
AIR INJECTION VENT WELL
CONSTRUCTION DETAIL

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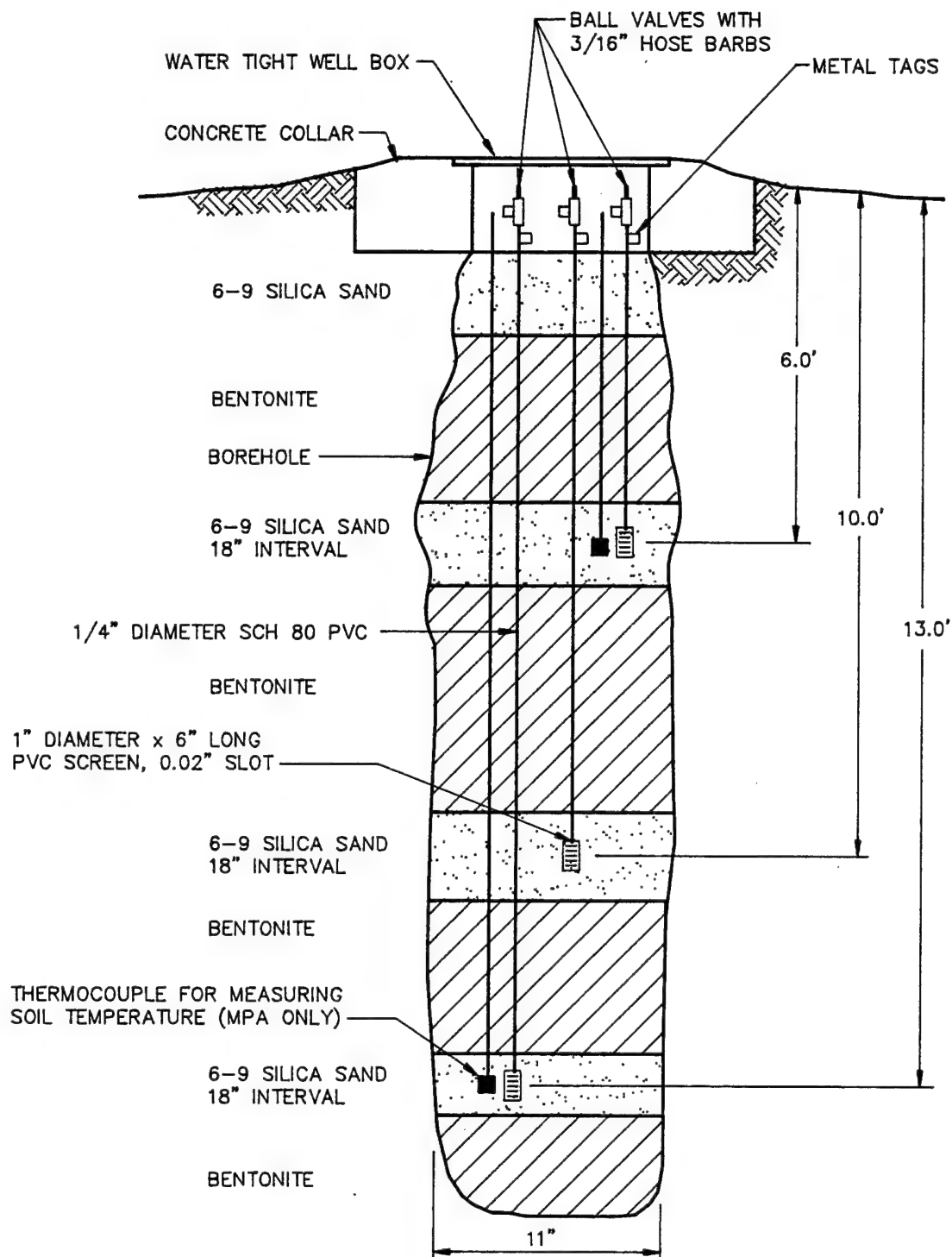


FIGURE 3.3

AREA H
MONITORING POINT
CONSTRUCTION DETAIL

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Denver, Colorado

ES

infiltration of bentonite slurry additions. Additional details on VW and MP construction can be found in Section 4 of the protocol document.

3.2 Area K

Figure 3.4 illustrates the proposed locations of the central VW and MPs at this site. The final locations of these wells may vary slightly from the proposed locations if significant fuel contamination is not observed in the boring for the central VW. Based on site investigation data, the central VW should be located near free product recovery well K, which is located in an area which has recently had up to 1 foot of floating free product. Soils in this area are expected to be oxygen depleted (<2%) due to high hydrocarbon levels, and increased biological activity should be stimulated by oxygen-rich soil gas ventilation during pilot test operations.

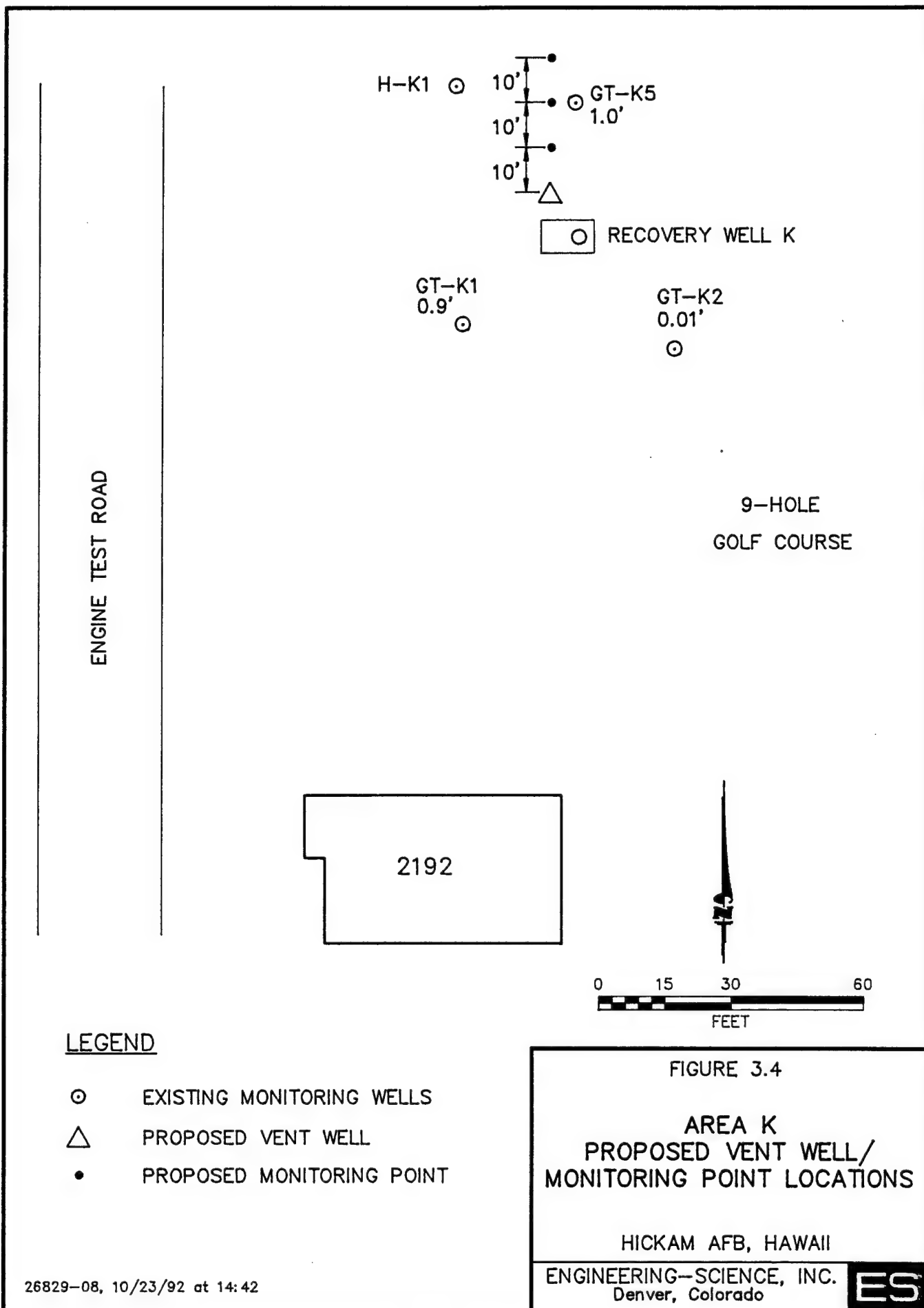
Due to the relatively shallow depth of contamination at this site and the experience that ES has had with this soil type, the potential radius of venting influence around the central air injection well is expected to be approximately 30 feet. Three vapor MPs will be located within a 30-foot linear distance of the central VW (Figure 3.4). A fourth vapor MP, to be located upgradient of the site, will be used to measure background levels of oxygen and carbon dioxide and to determine if natural carbon sources are contributing to oxygen uptake during the *in situ* respiration test.

The VW will be located approximately 3 feet north of the recovery well enclosure. The VW will be constructed of 4-inch inside diameter (ID) Schedule 40 polyvinyl chloride (PVC), with a 4-foot interval of 0.04-inch slotted screen set at 4 to 8 feet bgs. Flush-threaded PVC casing and screen with no organic solvents or glues will be used. The filter pack will be clean, well rounded silica sand with a 6-9 grain size and will be placed in the annular space of the screened interval. A 3-foot layer of bentonite will be placed directly over the filter pack. The first 6 inches of bentonite will consist of bentonite pellets hydrated in place with potable water. This layer of pellets will prevent the addition of bentonite slurry from saturating the filter pack. The remaining 30 inches of bentonite will be fully hydrated and mixed aboveground, and the slurry will be tremied into the annular space to produce an air-tight seal above the screened interval. A complete surface seal is necessary in order to prevent injected air from short circuiting to the surface during the bioventing test. Figure 3.5 illustrates the proposed VW construction for this site.

A typical vapor MP installation design for this site is shown in Figure 3.6. Soil gas oxygen and carbon dioxide concentrations will be monitored at a depth of approximately 6 feet at each location. The exact depth of each MP will be determined based on the interval of highest soil contamination. As with the central VW, several inches of bentonite pellets will be used to shield the filter pack from rapid infiltration of bentonite slurry additions.

3.3 Site 2

Figure 3.7 illustrates the proposed locations of the central VW and MPs at Site 2. The test area will be located near the approximate location of a known cesspool drain where fuel-contaminated wastewater from storage tanks has been disposed of



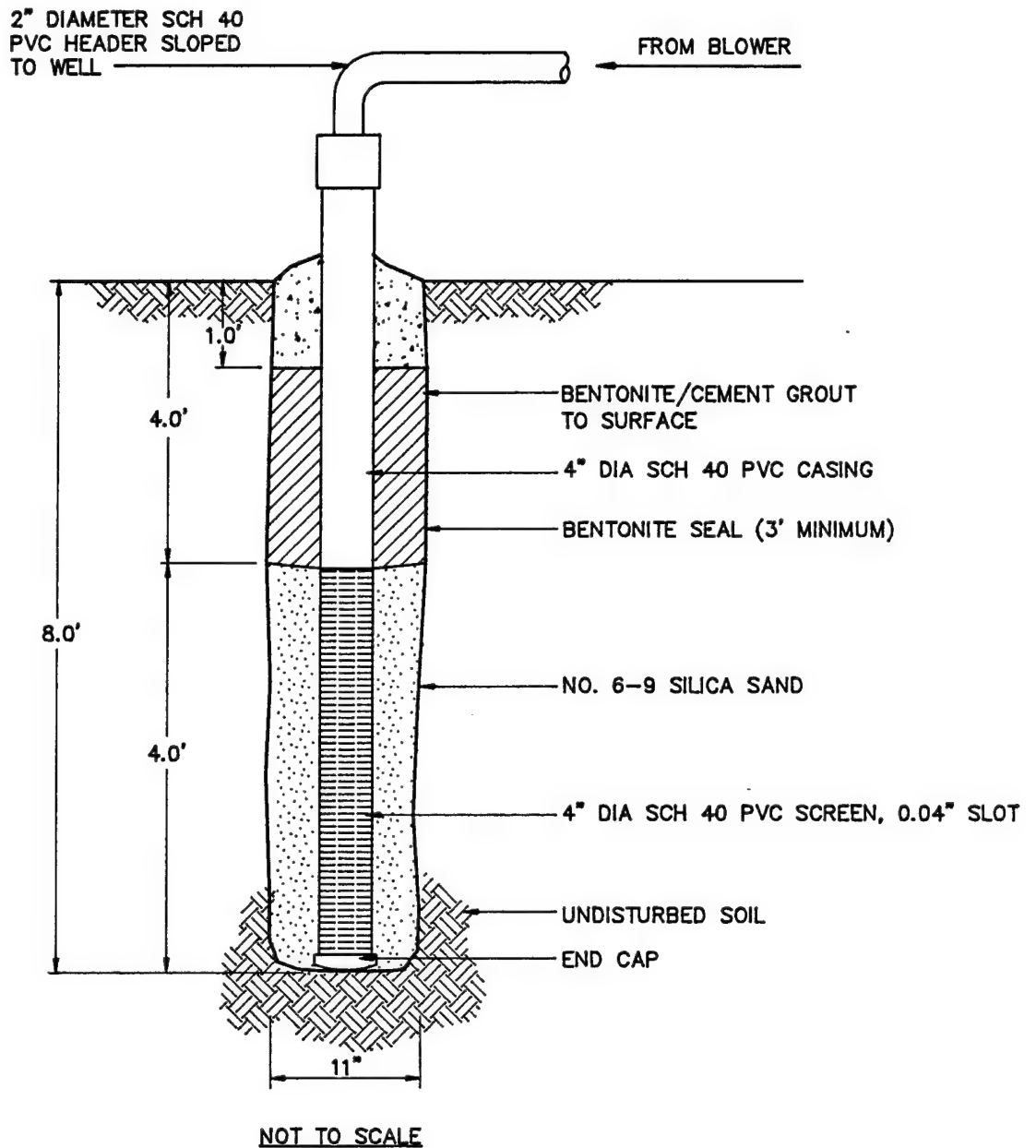


FIGURE 3.5
AREA K
INJECTION VENT WELL
CONSTRUCTION DETAIL

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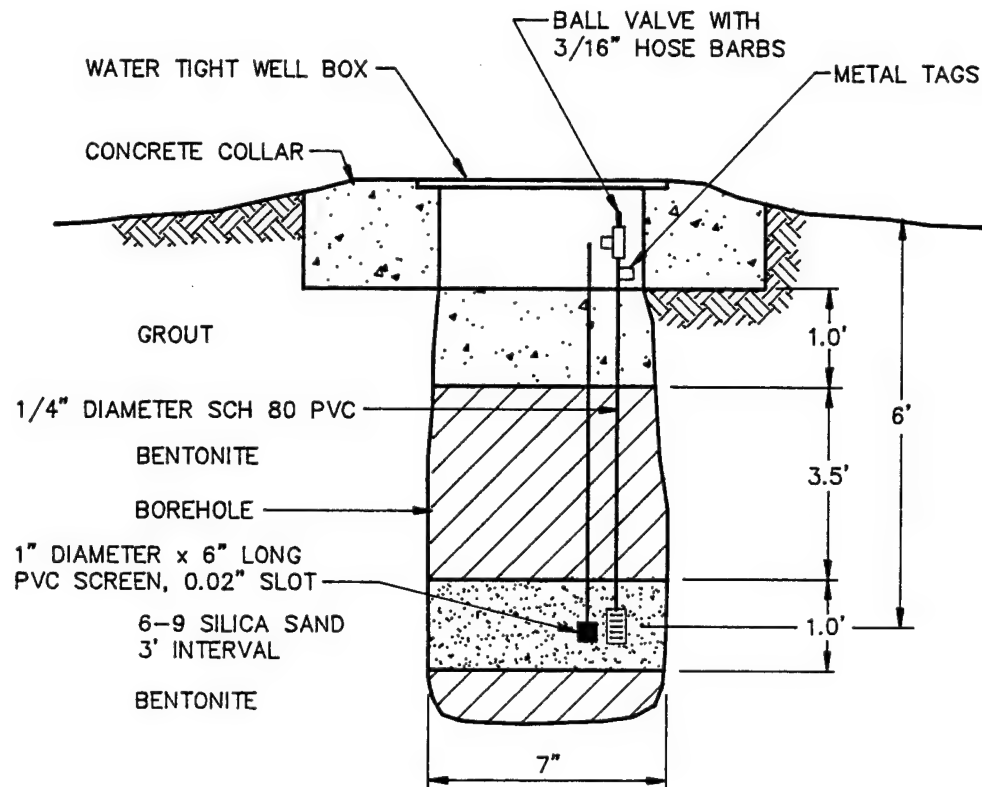


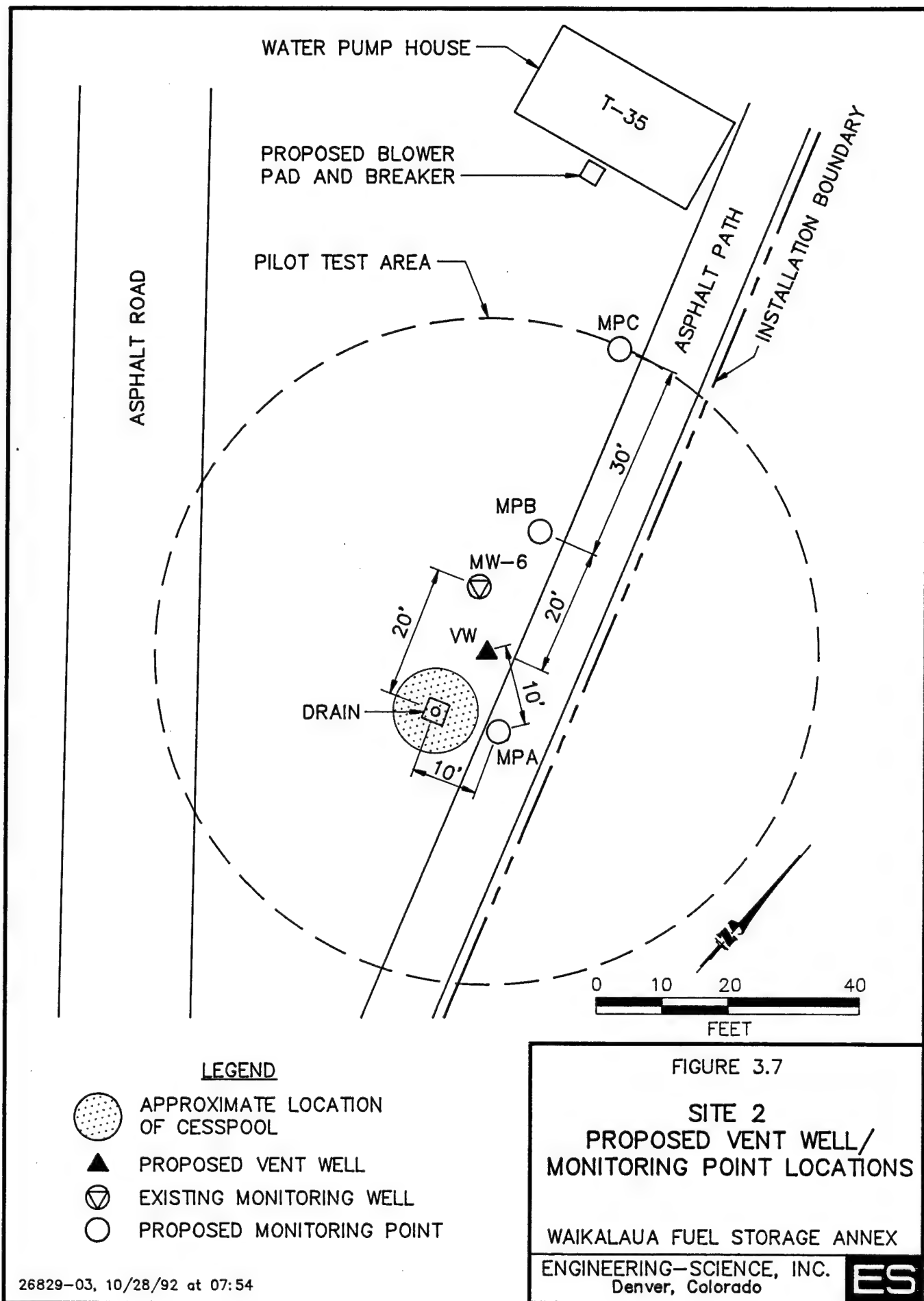
FIGURE 3.6

AREA K
MONITORING POINT
CONSTRUCTION DETAIL

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into the ground by seepage. Monitoring well MW-6 is located approximately 20 feet northwest of the cesspool but will not be used during testing. The final locations of the pilot test wells may vary slightly from the proposed locations if significant fuel contamination is not observed in the boring for the central VW.

Based on the deep contamination and the fractured-rock geology, the potential radius of venting influence around the central air injection well is expected to be exceed 50 feet. Three vapor MPs will be located within a 50-foot linear distance of the central VW. A fourth vapor MP will be located upgradient of the site and will be used to measure background levels of oxygen and carbon dioxide and to determine if natural carbon sources are contributing to oxygen uptake during the *in situ* respiration test.

The VW will be constructed of 4-inch ID Schedule 40 PVC, with an approximate 85-foot interval of 0.04-inch slotted screen set at approximately 15 to 100 feet bgs. Flush-threaded PVC casing and screen with no organic solvents or glues will be used. The filter pack will be clean, well-rounded silica sand with a 6-9 grain size and will be placed in the annular space of the screened interval. A 3-foot layer of bentonite will be placed directly over the filter pack. The first 6 inches of bentonite will consist of bentonite pellets hydrated in place with potable water. This layer of pellets will prevent the rapid addition of bentonite slurry from saturating the upper portion of the filter pack. The remaining 30 inches of bentonite will be fully hydrated and mixed aboveground, and then tremied into the annular space to produce an air-tight seal above the screened interval. A complete surface seal is necessary in order to prevent injected air from short-circuiting to the surface during the bioventing test. Figure 3.8 illustrates the proposed central VW construction for this site.

A typical multi-depth vapor MP installation for this site is shown in Figure 3.9. Soil gas oxygen and carbon dioxide concentrations will be monitored at approximate depth intervals of 15 feet, 45 feet, and 75 feet at each location. Multi-depth monitoring will confirm that the entire soil profile is receiving oxygen, and be used to measure fuel biodegradation rates at all depths. The spaces between monitoring intervals will be sealed with bentonite to isolate the intervals. As with the central VW, several inches of bentonite pellets will be used to shield the filter pack from rapid infiltration of bentonite slurry additions. Additional details on VW and MP construction can be found in Section 4 of the protocol document.

3.4 Handling of Drill Cuttings

All drill cuttings will be collected in U.S. Department of Transportation (DOT) approved containers. The containers will be labeled and placed in the Hickam AFB hazardous materials storage area. These drill cuttings will become the responsibility of Hickam AFB, and will be analyzed, handled, and disposed of in accordance with the current procedures for ongoing remedial investigations.

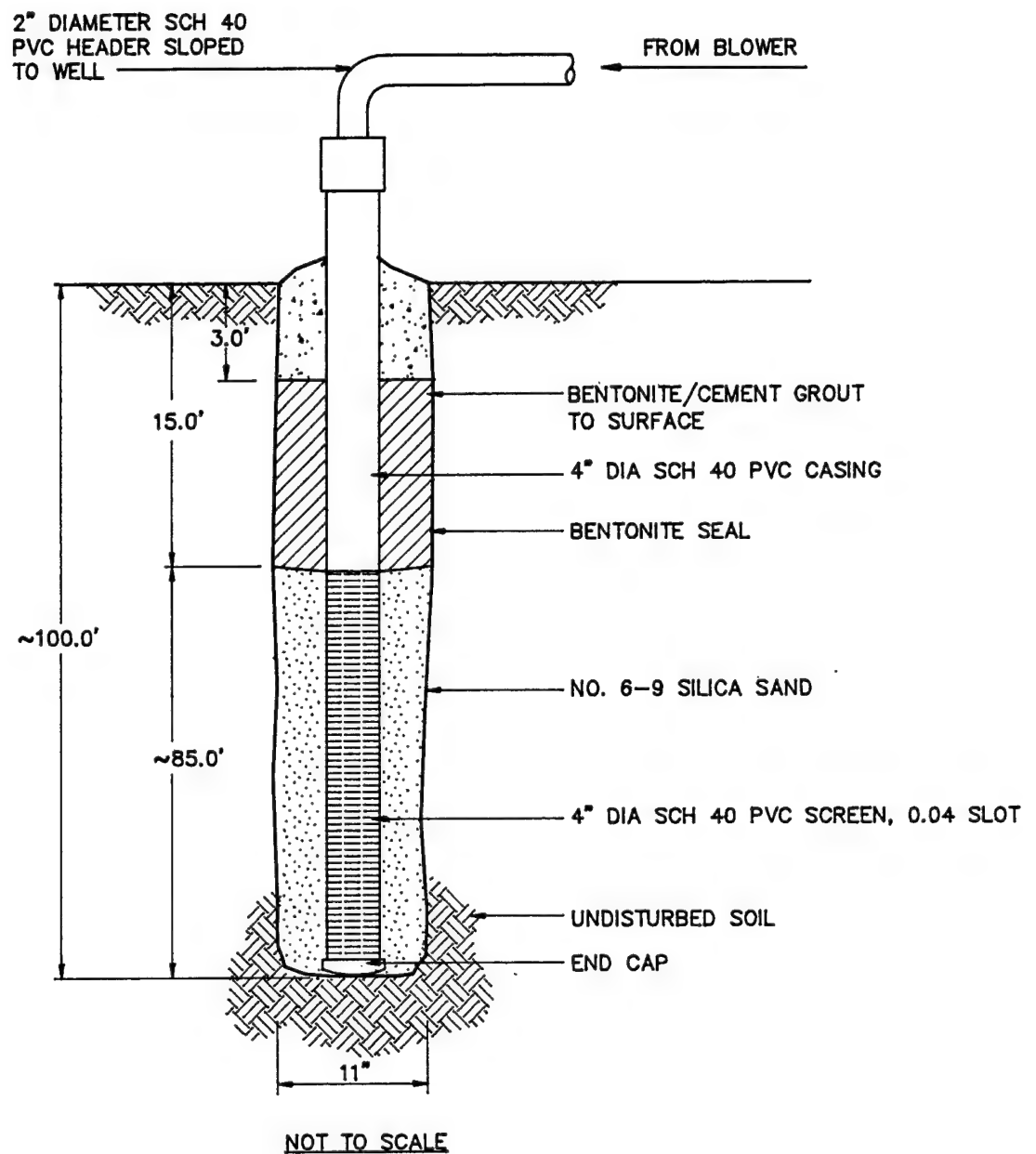


FIGURE 3.8

STIE 2
INJECTION VENT WELL
CONSTRUCTION DETAIL

WAIKALAU FUEL STORAGE ANNEX

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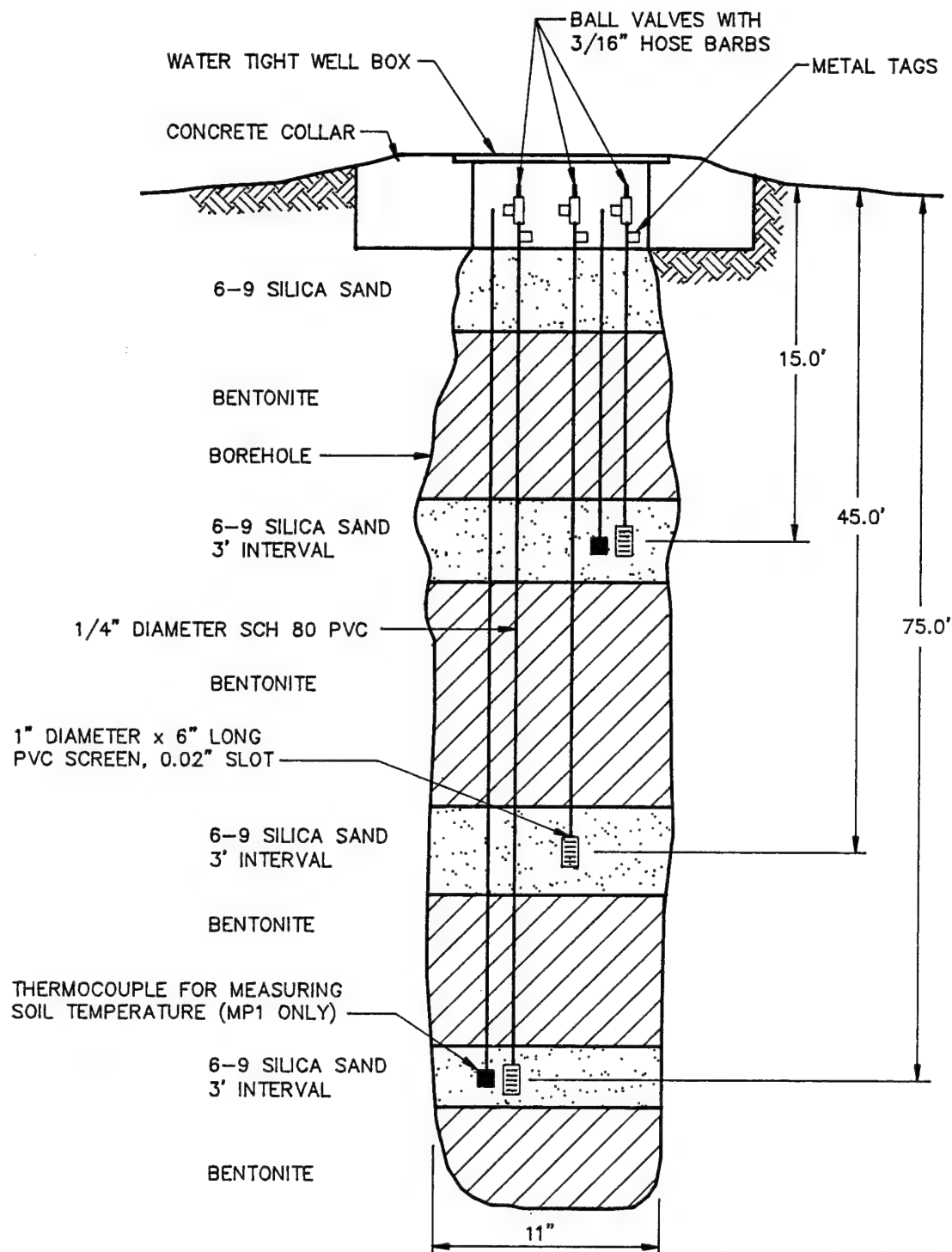


FIGURE 3.9

**SITE 2
MONITORING POINT
CONSTRUCTION DETAIL**

WAIKALAU FUEL STORAGE ANNEX

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3.5 Soil and Soil Gas Sampling

3.5.1 Soil Samples

Three soil samples will be collected from each pilot test area during the installation of the VW and MPs. Sampling procedures will follow those outlined in the protocol document (Hinchee et al., 1992). One sample will be collected from the most contaminated interval of each VW boring, and one sample will be collected from the interval of highest apparent contamination in each of the borings for the two MPs closest to the VW. Soil samples will be analyzed for TRPH; benzene, toluene, ethylbenzene, and xylenes (BTEX); soil moisture, pH; particle sizing; alkalinity; total iron; and nutrients.

Samples for TRPH and BTEX analysis will be collected using a split-spoon sampler containing brass tube liners. Soil samples collected in the brass tubes for TRPH and BTEX analyses will be immediately trimmed, and the ends will be sealed with aluminum foil or Teflon® fabric held in place by plastic caps. Soil samples collected for physical parameter analyses will be placed into glass sample jars or other appropriate sample containers as specified in the base sample handling plan. Soil samples will be labelled following the nomenclature specified in the protocol document (Section 5), wrapped in plastic, and placed in a cooler for shipment. A chain-of-custody form will filled out, and the cooler shipped to the ES laboratory in Berkeley, California for analysis. This laboratory has been audited by the Air Force and meets all quality assurance/quality control and certification requirements for the State of California.

3.5.2 Soil Gas Samples

A total hydrocarbon vapor analyzer will be used during augering to screen split-spoon soil samples for intervals of significant fuel contamination. Initial soil gas samples will be collected in SUMMA® canisters in accordance with the *Bioventing Field Sampling Plan* (ES, 1992) from the VW and from the MPs closest to and furthest from the VW. Additionally, these soil gas samples will be used to predict potential air emissions, to determine the reduction in BTEX and total volatile hydrocarbons (TVH) during the 1-year test, and to detect any migration of these vapors from the source area.

Soil gas sample canisters will be placed in a small cooler and packed with foam pellets to prevent excessive movement during shipment. Samples will not be sent on ice to prevent condensation of hydrocarbons. A chain-of-custody form will be filled out, and the cooler will be shipped to the Air Toxics laboratory in Rancho Cordova, California for analysis.

3.6 Blower System

A 2.5-horsepower regenerative blower capable of injecting up to 50 standard cubic feet per minute (scfm) at 2 pounds per square inch will be used to conduct the initial air permeability test and *in situ* respiration tests at each site. At the Area H and Area K spill sites, the blowers will be placed in a small "dog house" inside the existing recovery well enclosures. At Site 2, the blower unit will be located near building T-35, and a 2-inch air supply line will be placed in a shallow trench.

Figure 3.10 is a schematic of a typical air injection system used for pilot testing. The maximum power requirement anticipated for these pilot tests is a 230-volt, single-phase, 30-amp service. Additional details on power supply requirements are described in Section 5.0, Base Support Requirements.

3.7 In Situ Respiration Test

The objective of the *in situ* respiration test is to determine the rate at which soil bacteria degrade petroleum hydrocarbons. Respiration tests will be performed at every vapor MP where bacteria biodegradation of hydrocarbons is indicated by low oxygen levels and elevated carbon dioxide concentrations in the soil gas. Air will be injected into each MP depth interval containing low levels (<2%) of oxygen as described in Section 5.7 of the protocol document. A 20-hour air injection period will be used to oxygenate local contaminated soils. At the end of the 20-hour air injection period, the air supply will be cut off, and oxygen and carbon dioxide levels will be monitored for the following 48 to 72 hours. The decline in oxygen and increase in carbon dioxide concentrations over time will be used to estimate rates of bacterial degradation of fuel residuals. Helium will also be injected at one or two MPs to estimate oxygen diffusion rates in site soils. This estimated rate of diffusion will be used to account for oxygen diffusion in the overall loss of oxygen from the soil.

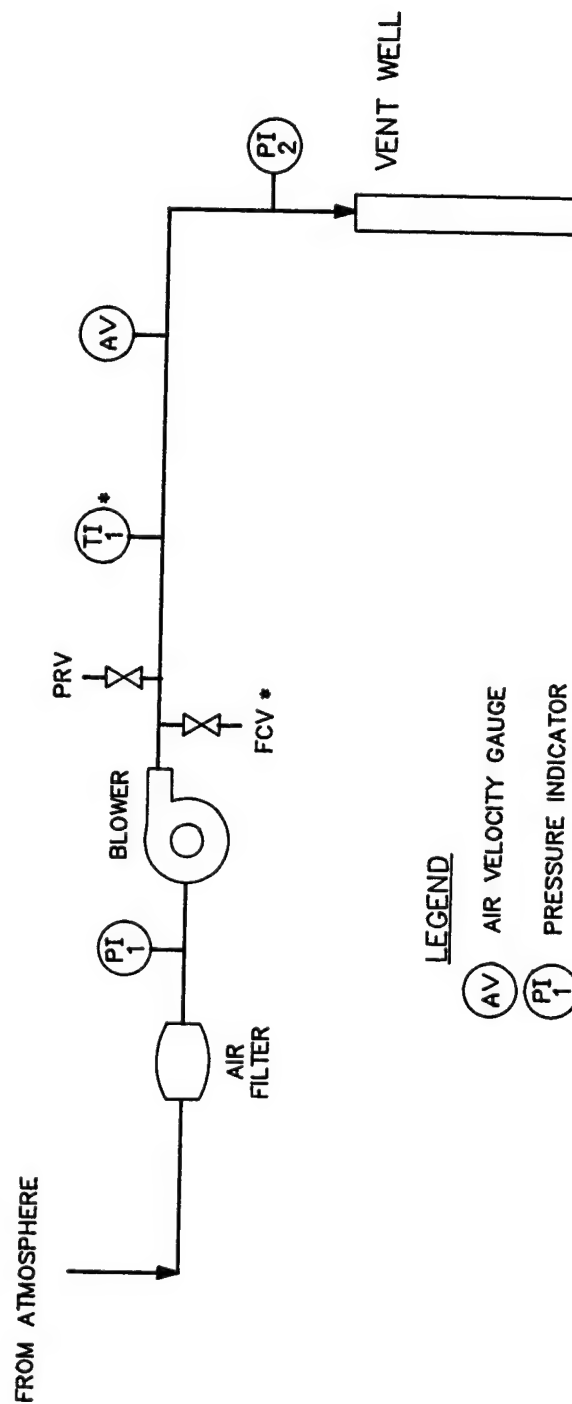
3.8 Air Permeability Test

The objective of the air permeability test is to determine the extent of the subsurface that can be oxygenated using the VWs. Air will be injected into the 4-inch-diameter VWs using the blower unit, and pressure response will be measured at each MP with differential pressure gauge to determine the region influenced by the unit. Oxygen will also be monitored in the MPs to ascertain that oxygen levels in the soil increase as the result of air injection. One air permeability test lasting 4 to 8 hours will be performed at each site.

3.9 Hydrocarbon Emissions Monitoring

Although the objective of using a low rate of air injection is to maximize *in situ* biodegradation and minimize volatile hydrocarbon emissions, some short-term loss of volatiles to the atmosphere can occur at sites with shallow contamination. The possibility of such emissions exists at Sites H and K because fuel contamination is known to exist within 8 to 10 feet of the ground surface. Because contamination at Site 2 occurs below a depth of approximately 25 feet, no emissions are anticipated at Site 2.

Hydrocarbon emissions will be monitored at all sites by placing a simple 1-cubic-foot flux chamber over the soil at selected points within the test area. The flux chamber will collect a 1-liter per minute gas sample from the soil surface and pass the sample through a portable hydrocarbon gas analyzer. The analyzer will be calibrated to measure total volatile hydrocarbons with a 500 ppmv hexane standard. Hydrocarbon emissions will be monitored before and during the air permeability test to determine if any increase in emissions occurs due to this low rate of air injection.



LEGEND

- (AV) AIR VELOCITY GAUGE
- (PI₁) PRESSURE INDICATOR
- (TI₁) TEMPERATURE INDICATOR
- FCV FLOW CONTROL VALVE
- PRV PRESSURE RELIEF VALVE
- * OPTIONAL

FIGURE 3.10

BLOWER SYSTEM INSTRUMENTATION DIAGRAM FOR AIR INJECTION

HICKAM AFB, HAWAII

ENGINEERING-SCIENCE, INC.
Denver, Colorado

3.10 Installation of Extended Pilot Test Bioventing System

Extended 1-year pilot test systems will also be installed at Area H, Area K, and Site 2. At each site, the base will be requested to provide a 230-volt, single-phase, 30-amp breaker box, one 230-volt receptacle, and two 115-volt receptacles. Depending on the availability of a base electrician, a base electrician or a licensed electrician subcontracted to ES will assist in wiring the blowers to available power. The blowers will be housed in small, prefabricated sheds to provide protection from the weather. The systems will be in operation for 1 year, and every 6 months ES personnel will conduct *in situ* respiration tests to monitor the long-term performance of the bioventing systems. Weekly system checks will be performed by Hickam AFB personnel. If required, major maintenance of the blower unit may be performed by ES-Honolulu personnel. Detailed blower system information and a maintenance schedule will be included in the operation and maintenance (O&M) manual provided to the base. More detailed information regarding the test procedures can be found in the protocol document.

4.0 EXCEPTIONS TO PROTOCOL PROCEDURES

The procedures that will be used to measure the air permeability of the soil and *in situ* respiration rates are described in Sections 4 and 5 of the protocol document. No exceptions to the protocol procedures are anticipated.

5.0 BASE SUPPORT REQUIREMENTS

The following base support is needed prior to the arrival of the drilling subcontractor and the ES test team:

- Assistance in obtaining drilling and digging permits from Hickam AFB and the State of Hawaii Department of Natural Resources (if required).
- Installation of 230-volt, 30-amp single-phase service and a breaker box with one 230-volt receptacle and two 115-volt receptacles at each test site. The breaker should be located within 50 feet of the central VW location at each site.
- Provision of any paperwork required to obtain gate passes and security badges for approximately three ES employees, two drillers, and an electrician (if a base electrician is not available). Vehicle passes will be needed for one truck and a drill rig.

During the initial testing, the following base support is needed at each site:

- Twelve square feet of desk space and a telephone in a building located as close to the site as practical.
- The use of a facsimile machine for transmitting 15 to 20 pages of test results.
- A decontamination pad where the driller can clean augers between borings.

- Acceptance of responsibility by Hickam AFB for drill cuttings from VW and MP borings, including any drum sampling to determine hazardous waste status. Drill cutting samplings and disposal is not included in the bioventing research contract, however, arrangements for sampling could be made using other ES contracts.

During the 1-year extended pilot test, base personnel will be required to perform the following activities:

- Check each blower system once per week to ensure that it is operating and to record the air-injection pressure. ES will provide a brief training session on this procedure.
- If a blower stops working, notify Mr. Doug Downey or Ms. Gail Saxton, ES-Denver (303) 831-8100, or Mr. Jim Williams, AFCEE (512) 536-5246.
- Arrange site access for an ES technician to conduct *in situ* respiration tests approximately 6 months and 1 year after the initial pilot test.

6.0 PROJECT SCHEDULE

The following schedule is contingent upon timely approval of this pilot test work plan.

<u>Event</u>	<u>Date</u>
Draft Test Work Plan to AFCEE/Hickam AFB	22 September 1992
Initial Site Visit	14 October 1992
Regulatory Approval of Second Draft	1 December 1992
Begin Initial Pilot Test	February 1993
Interim Results Report	April 1993
Respiration Test	October 1993
Final Respiration Test	February 1994

7.0 POINTS OF CONTACT

Mr. William Barry
15 CES/DEV
Hickam AFB, HI 96853-5000
(808) 449-7519

Major Ross Miller/Mr. Jim Williams
AFCEE/EMVR
Brooks AFB, TX 78235-5000
(512) 536-5246

PART II
DRAFT INTERIM PILOT TEST RESULTS REPORT
AREAS H AND K, AND SITE 2
HICKAM AFB, HAWAII

Prepared for:

Air Force Center for Environmental Excellence
Brooks AFB, Texas

and

15th Civil Engineering Squadron/DEV
Hickam AFB, Hawaii

August 1993

by:

Engineering-Science, Inc.
1700 Broadway, Suite 900
Denver, Colorado

Mr. Doug Downey
Engineering-Science, Inc.
1700 Broadway, Suite 900
Denver, CO. 80290
(303) 831-8100
Fax (303) 831-8208

8.0 REFERENCES

- Engineering-Science, Inc. 1992. *Field Sampling Plan for AFCEE Bioventing*.
Groundwater Technology. 1985. *Site Investigation Report*. November.
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PART II
DRAFT
INTERIM PILOT TEST RESULTS REPORT
AREAS H AND K AND SITE 2
HICKAM AFB, HAWAII

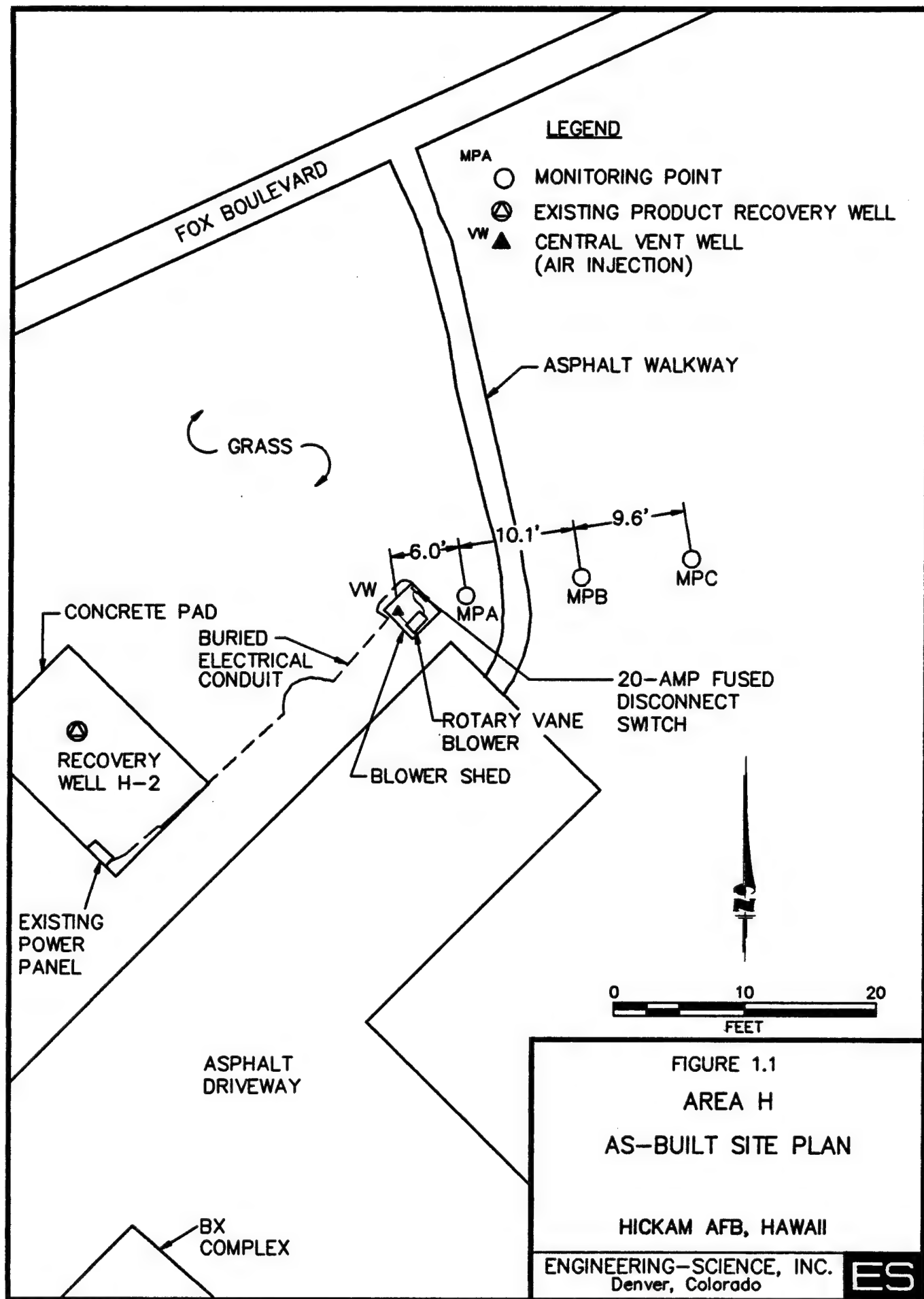
Initial bioventing pilot tests were completed by Engineering-Science, Inc. (ES) at Area H and Area K on Hickam Air Force Base (AFB), Hawaii, and at Site 2 on the Waikakalaua Fuel Storage Annex during the period of March 12 through May 13, 1993. The purpose of this Part II report is to describe the results of the initial bioventing pilot tests at Area H, Area K, and Site 2, and to make specific recommendations for extended testing to determine the long-term impact of bioventing on site contaminants. Descriptions of the history, geology, and contamination at each site are contained in Part I, the Bioventing Pilot Test Work Plan.

1.0 AREA H

1.1 Pilot Test Design and Construction

Installation of an air injection vent well (VW) and three vapor monitoring points (MPs) at Area H took place on March 22 through 24, 1993. Drilling services were provided by Geolabs-Hawaii, Inc. of Honolulu, Hawaii. Well installation and soil sampling were directed by Mr. John Ratz, the ES site manager, and Mr. Craig Miller, the ES site geologist. The following sections describe the final design and installation of the bioventing system at this site.

One VW, three MPs (MPA, MPB, and MPC), and a blower unit were installed at Area H. Figures 1.1 and 1.2, respectively, depict the locations of and a hydrogeologic cross section for the VW and MPs completed at Area H. A background MP was not installed at Area H because there were no areas of uncontaminated soil at the site accessible for drilling. To characterize soil gas in uncontaminated soils, a soil gas probe (HI-BG) was driven to a depth of 4.5 feet below ground surface (bgs) at a location 3 feet west of existing groundwater monitoring well BKG-MW-29. BKG-MW-29 was installed at approximately the corner of Ohana Nui Circle and Puakala Street, in a residential area on the eastern side of Hickam AFB.



1.1.1 Air Injection Vent Well

The air injection VW was installed following procedures described in the Air Force Center for Environmental Excellence (AFCEE) bioventing protocol document (Hinchee et al., 1992). Figure 1.3 shows construction details for the VW. The VW was installed in silt/sandstone and clayey sand that contained hydrocarbon contamination below 18 feet bgs. Groundwater was encountered 20 feet bgs. The VW was constructed using 4-inch-diameter, Schedule 40 polyvinyl chloride (PVC) casing, with 10 feet of 0.02-inch slotted PVC screen installed from 9.5 to 19.5 feet bgs. The annular space between the well casing and borehole was filled with number 3 silica sand from the bottom of the borehole to approximately 6 inches above the well screen. Approximately 3 feet of granular bentonite was placed above the sand in 6-inch lifts, with each lift being hydrated in place. On top of the bentonite layer, approximately 6 feet of cement grout was placed and was finished flush with the existing grass surface. The well casing was cut off approximately 6 inches above the surface, and the casing was connected to a galvanized steel header using a rubber pipe coupler.

1.1.2 Monitoring Points

Three MPs (MPA, MPB, and MPC) were constructed at Area H, and three screens were installed at each MP location. At MPA, the screens were installed at 6-, 12.3-, and 16.5-foot depths. Screens at MPB were installed at 6.3-, 10.6-, and 16.5-foot depths, and the screens at MPC were installed at 5.8-, 12.4-, and 16.8-foot depths. The as-built construction detail for MPC is illustrated in Figure 1.4. MPA and MPB were constructed in a similar fashion, although screened depths and sand and bentonite thicknesses vary slightly from those shown in Figure 1.4. Each MP monitoring interval was constructed using a 6-inch section of 1-inch-diameter PVC well screen and a 0.25-inch-diameter Schedule 80 PVC riser pipe extending to the ground surface. At the top of each riser, a ball valve and a 3/16-inch hose barb were installed. The top of each MP was completed with a flush-mounted metal well protector set in a concrete base. Thermocouples were installed at the 6- and 16.5-foot depths at MPA to measure soil temperature variations.

1.1.3 Blower Unit

For both the initial and extended pilot tests, a 1.5-horsepower Gast® model 2567-P102 rotary-vane blower unit was used. During the initial air permeability test, the unit was energized by 230-volt, single-phase, 20-amp power from a temporary exterior receptacle. The fixed unit is energized by 230-volt, single-phase, 20-amp line power from a newly installed underground power line and aboveground breaker installed by base electricians. The configuration, instrumentation, and specifications for this blower system are shown on Figure 1.5. The blower is currently transporting air at a flow rate of approximately 19 actual cubic feet per minute (acfm) for the extended pilot test. After blower installation and startup, ES engineers provided an operation and maintenance (O&M) manual, including maintenance instructions, equipment specifications, and monitoring forms, to base personnel. A copy of the O&M instructions is provided in Appendix A.

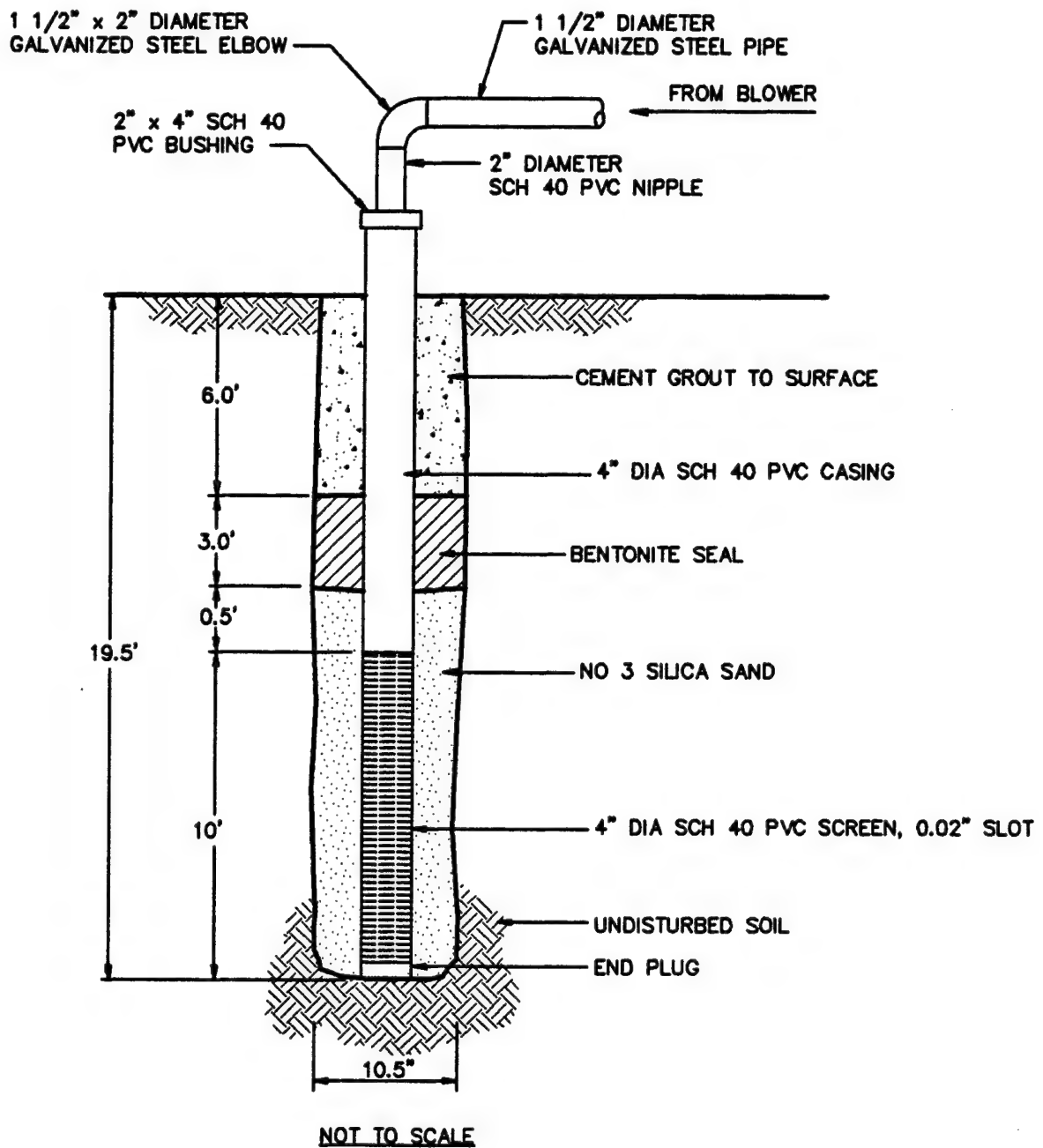


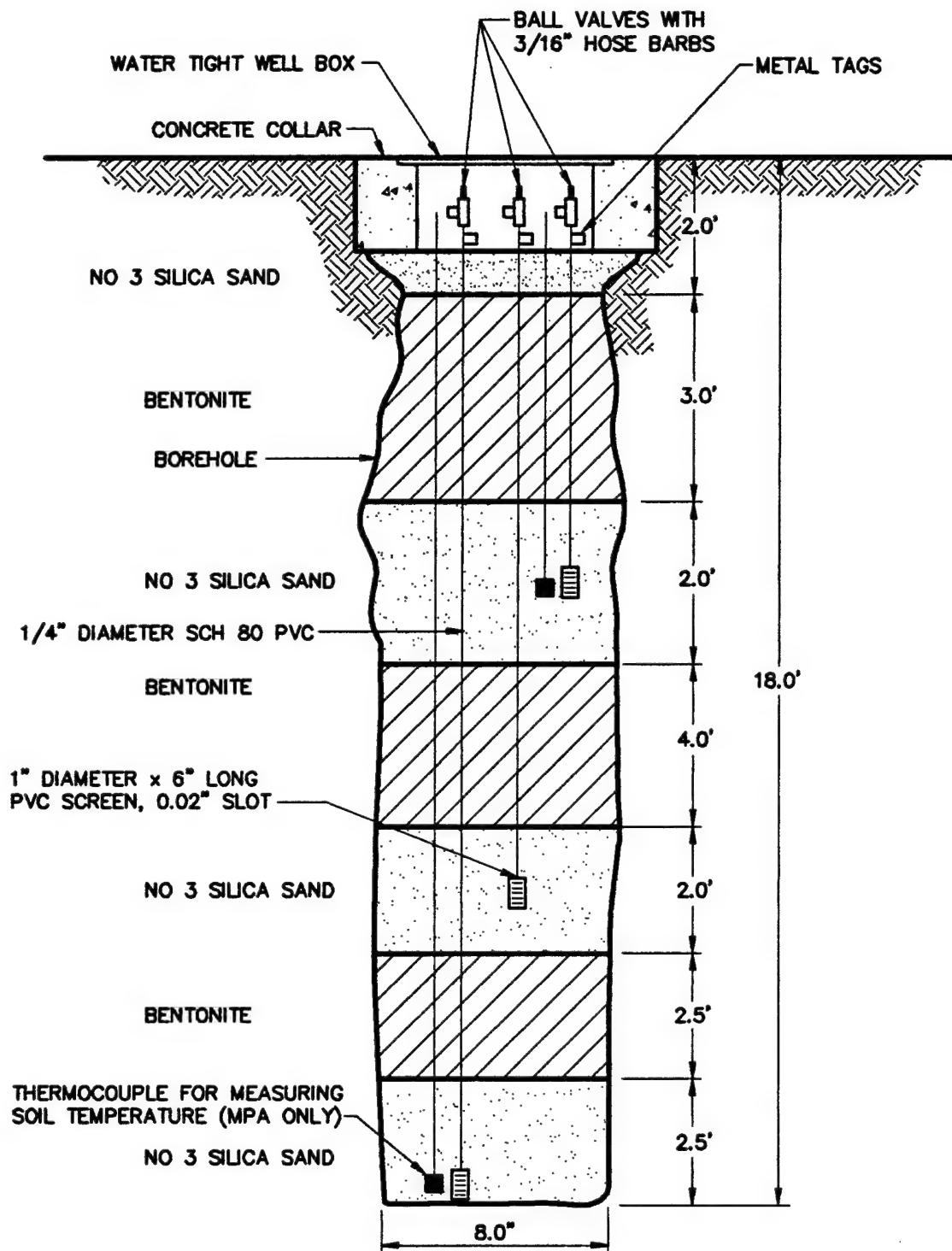
FIGURE 1.3

AREA H
AS-BUILT INJECTION VENT WELL
CONSTRUCTION DETAIL

HICKAM AFB, HAWAII

ENGINEERING-SCIENCE, INC.
Denver, Colorado

ES



NOT TO SCALE

FIGURE 1.4

AREA H
AS-BUILT MONITORING POINT
MPC CONSTRUCTION DETAIL

HICKAM AFB, HAWAII

ENGINEERING-SCIENCE, INC.
Denver, Colorado

ES

LEGEND

- ① INLET AIR FILTER - GAST® MODEL AA 905G
- ② 1 1/2 HORSEPOWER ROTARY VANE BLOWER - GAST® MODEL 2567-P102
- ③ AUTOMATIC PRESSURE RELIEF VALVE - GAST® MODEL AA307
- ④ MANUAL PRESSURE RELIEF (BLEED) VALVE 3/4" GATE
- ⑤ TEMPERATURE GAUGE (0-250° F)
- ⑥ PRESSURE GAUGE (0-10 psi)
- ⑦ DISCONNECT SWITCH - 230V/SINGLE PHASE/20 AMP

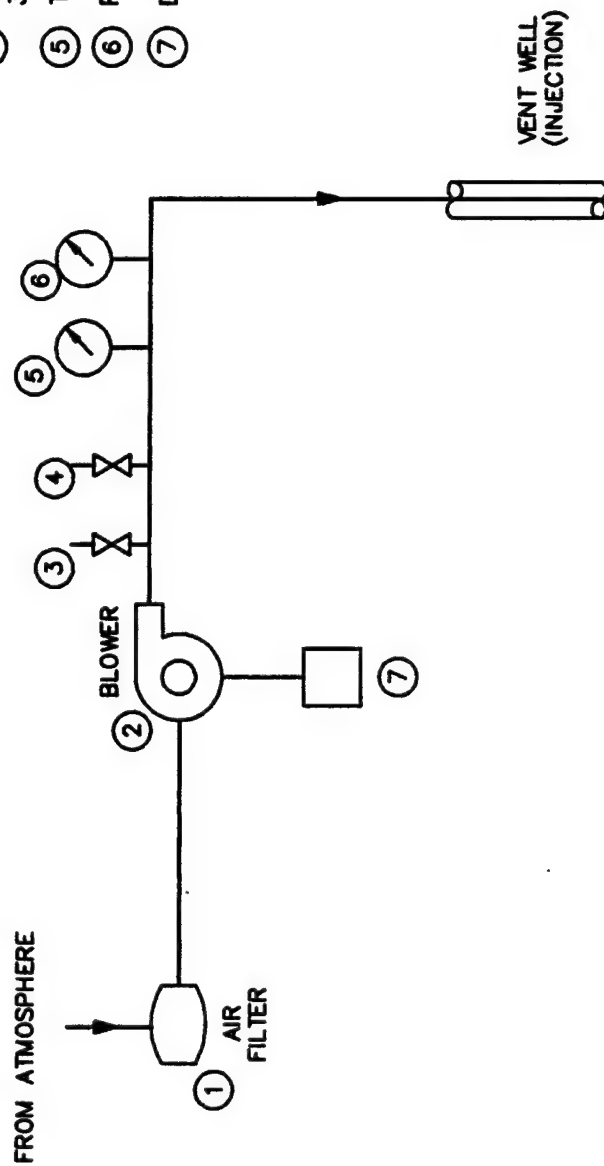


FIGURE 1.5

AREA H AS-BUILT BLOWER SYSTEM FOR AIR INJECTION

HICKAM AFB, HAWAII

ENGINEERING-SCIENCE, INC.
Denver, Colorado

ES

1.2 PILOT TEST SOIL AND SOIL GAS SAMPLING RESULTS

1.2.1 Sampling Results

The geology at Area H generally consists of clay, sand, and coralline rubblestone, underlain by layers of siltstone, claystone, and sandstone. Basalt was encountered at depths between 18 and 20 feet bgs. Groundwater was encountered at a depth of approximately 20 feet bgs in the VW. Free product was encountered during the collection of soil gas samples from the deep MP screens at MPA and MPB. More detailed hydrogeologic information regarding Area H can be found in the hydrogeologic cross section (Figure 1.2) and the geologic boring logs (Appendix B).

Contaminated soils were identified based on visual appearance, odor, and results of total hydrocarbon analyzer field screening for volatile organic compounds (VOCs). Heavily contaminated soils were encountered below approximately 16 feet bgs in the VW and all MP boreholes. Soil and rock below 16 feet bgs had a strong hydrocarbon odor, and field VOC headspace concentrations from these depths ranged from 1,600 to 4,294 parts per million, volume per volume (ppmv) (Figure 1.2). Although soil and rock from 5 to 16 feet bgs displayed no physical evidence of contamination, field VOC headspace concentrations were as high as 453 ppmv. It is possible that soil gas at these depths has become contaminated by fuel vapors that have volatilized from the free product layer and migrated upward toward the ground surface.

Soil samples for laboratory analysis were collected from 18-inch split- spoon samplers with 2-inch-diameter brass liners. Soil samples were screened for VOCs using a hydrocarbon analyzer to determine the presence of contamination and to select soil samples for laboratory analysis. Soil samples for laboratory analysis were collected from the VW, MPA, and MPB at a depth of approximately 17.5 to 18 feet bgs.

Soil gas samples were collected from the completed VW and at 6 feet bgs from MPA and at 12.4 feet bgs from MPC. Soil gas samples were collected using 3-liter Tedlar® bags and vacuum chambers. After the samples were collected with Tedlar® bags, they were transferred to 1-liter SUMMA® canisters and shipped to the laboratory.

Soil samples were shipped to the Pace, Inc. laboratory in Novato, California, for chemical and physical analysis. Soil samples were analyzed for total recoverable petroleum hydrocarbons (TRPH); benzene, toluene, ethylbenzene and xylenes (BTEX); iron; alkalinity; total Kjeldahl nitrogen (TKN); and several physical parameters. Soil gas samples were shipped to Air Toxics, Inc. in Rancho Cordova, California, for total volatile hydrocarbon (TVH) and BTEX analysis. The TVH analyses were referenced to JP-4 jet fuel. The results of these analyses are provided in Table 1.1. Chain-of-custody forms are provided in Appendix B.

Results for TRPH in the soil samples appear to be lower than would typically be expected based on field screening results, observations made during drilling (strong fuel odor), and relatively high BTEX results (BTEX concentrations are typically

TABLE 1.1
AREA H
SOIL AND SOIL GAS ANALYTICAL RESULTS
HICKAM AFB, HAWAII

Analyte (Units) ^{a/}	Sample Location-Depth (feet below ground surface)		
<u>Soil Hydrocarbons</u>	<u>VW-18</u>	<u>MPA-18</u>	<u>MPB-18</u>
TRPH (mg/kg)	ND ^{b/}	23.9	9
Benzene (mg/kg)	2.25	ND	6.0
Toluene (mg/kg)	8.7	1.2	6.0
Ethylbenzene (mg/kg)	6.3	2.0	8.1
Xylenes (mg/kg)	16.0	2.6	4.0
<u>Soil Gas Hydrocarbons</u>	<u>VW</u>	<u>MPA-6</u>	<u>MPC-12.4</u>
TVH (ppmv)	330,000	2,100	380,000
Benzene (ppmv)	ND	ND	ND
Toluene (ppmv)	ND	ND	ND
Ethylbenzene (ppmv)	26	0.15	57
Xylenes (ppmv)	ND	0.11	61
<u>Soil Inorganics</u>	<u>VW-18</u>	<u>MPA-18</u>	<u>MPB-18</u>
Iron (mg/kg)	77,100	76,300	72,000
Alkalinity (mg/kg as CaCO ₃)	990	1,800	1,600
pH (units)	9.0	8.9	9.0
TKN (mg/kg)	32	30	48
Phosphates (mg/kg)	3,300	3,300	3,700
<u>Soil Physical Parameters</u>	<u>VW-18</u>	<u>MPA-18</u>	<u>MPB-18</u>
Moisture (% wt.)	25.3	22.2	26.4
Gravel (%)	0	0	0
Sand (%)	64	56	58
Silt (%)	28	38	36
Clay (%)	8	6	6
<u>Soil Temperature (°F)</u>	<u>MPA-6</u>	<u>MPA-16.5</u>	
	80.1	79.3	

- a/ TRPH = total recoverable petroleum hydrocarbons; mg/kg = milligrams per kilogram;
TVH = total volatile hydrocarbons; ppmv = parts per million, volume per volume;
CaCO₃ = calcium carbonate; TKN = total Kjeldahl nitrogen, °F = degrees Fahrenheit.
- b/ ND = not detected.

much lower than TRPH concentrations in fuel-contaminated soils). The low TRPH analytical results may be the result of matrix interference.

1.2.2 Exceptions to Test Protocol Procedures

Procedures described in the protocol document (Hinchee et al., 1992) were used to complete the pilot test at Area H, with the following exception. Due to the widespread extent of fuel contamination, there were no suitable locations to install a background MP at Area H. Therefore, soil gas probe HI-BG was installed to provide background soil gas data for Area H, as well as Area K.

1.3 PILOT TEST RESULTS

1.3.1 Initial Soil Gas Chemistry

Prior to initiating air injection, all MPs and the VW were purged, and initial oxygen, carbon dioxide, and TVH concentrations were determined using portable gas analyzers, as described in the technical protocol document (Hinchee et al., 1992). Table 1.2 summarizes the initial soil gas chemistry at Area H. The results strongly indicate that biological fuel degradation is occurring in the vadose zone. Oxygen levels were below 5 percent in 4 of the 5 points sampled at Area H. In contrast, soil gas probe HI-BG contained oxygen at a concentration of 18.9 percent during initial sampling. Carbon dioxide was present at concentrations ranging from 0.6 to 10.6 percent in soil gas at Area H. Because the fuel-contaminated soil gas at Area H contains low oxygen relative to uncontaminated background soil gas, oxygen depletion in soil gas at Area H can be specifically attributed to petroleum hydrocarbon biodegradation rather than the consumption of naturally occurring soil organic matter. The high hydrocarbon concentrations in the deeper sampling locations are likely caused by the volatilization of fuel from the free product layer into fractures in the rock and pore space of the soil in the vadose zone at Area H.

Due to atypical hydrogeologic conditions at Area H, soil gas samples could be collected only from the VW, MPA-6, MPA-16.5, MPB-6.3, and MPC-12.4. At MPC-16.5, only free product and water could be extracted, even though the screen had been installed a minimum of 1 foot above the standing fluid level during MP and VW installation. It is possible that free product and groundwater were pulled upward into the MP screen through fractures in the rock or through soil pore space when vacuum was applied to MPC-16.5 to collect the sample. Soil gas could not be drawn through the remainder of the MP screens, indicating that these screens were installed in layers of stone with very low air permeability.

1.3.2 Air Permeability

An air permeability test was conducted at Area H according to protocol document procedures. Air was injected into the VW for approximately 26 hours at a rate of approximately 19 acfm and an average pressure of approximately 5.5 pounds per square inch (psi). The pressure response at each MP is listed in Table 1.3. Definite pressure influence was observed at MPA-16.5, MPB-16.5, and MPC-

TABLE 1.2
AREA H
INITIAL SOIL GAS CHEMISTRY
HICKAM AFB, HAWAII

MP	Depth (ft)	O ₂ (%)	CO ₂ (%)	Field TVH (ppmv)	Lab TVH (ppmv)
VW	9.5-19.5	0.2	2.6	>20,000	330,000
A	6	1.4	10.2	2,500	2,100
A	16.5	2.7	4.7	>20,000	NS ^{a/}
B	6.3	8.9	2.5	1,900	NS
C	12.4	0.8	0.6	>20,000	380,000
HI-BG	4.5	18.9	3.5	140	NS

a/ NS=not sampled.

TABLE 1.3
AREA H
PRESSURE RESPONSE DURING THE AIR PERMEABILITY TEST
HICKAM AFB, HAWAII

Depth (ft)	Pressure Response In MP (inches of water)						
	6	MPA 12.3	16.5	6.3	MPB 10.6	16.5	MPC 12.4
1.0	0	0	0.35	0.0	0.01	0.29	- ^{a/}
2.0	0	0.45*	0.40	-	-	-	-
3.0	0	0.65*	0.45	-	-	-	-
4.0	-	-	-	0.0	-	-	1.9
5.0	0.05	0.05*	0.8	0.0	0.02	0.02	0.0
6.0	-	-	-	-	-	-	-
7.0	0.05	0.05*	1.0	-	-	-	5.8
8.0	-	-	-	-	-	-	-
9.0	0.05	0.55*	1.2	0.0	0.02	0.49	-
10.0	-	-	-	-	-	-	7.95
15.0	0.05	1.55*	1.7	0.0	0.0	0.26	10.0
20.0	0.05	2.7*	2.7	-	-	-	9.62
35.0	0.05	3.95*	4.0	0.0	0.0	0.02	-
40.0	0.05	3.95*	2.55	0.02	0.03	0.085	16.5
65.0	0.05	4.7*	0.85	0.01	0.03	0.10	17.7
110.0	0.05	5.4*	3.15	0.0	0.01	0.24	18.0
140.0	0.05	5.4*	2.5	0.0	0.0	1.2	20.0
170.0	0.05	5.4*	1.15	0.0	0.0	0.06	18.4
1405.0	0.04	13.0*	0.45	0.02	0.02	0.02*	17.0

a/ - = no reading taken at this time.

* = vacuum.

12.4. The remainder of the MPs yielded no significant pressure influence. The vacuum observed at MPA-12.3 could be residual vacuum left in the soil and rock by prior purging and sampling attempts. These results indicate that the soil and rock in the vadose zone at Area H are impermeable, but injected air can move through the formation via preferential pathways, such as fractures or seams. An air permeability value was not calculated for Area H due to the atypical material that was encountered. Both the dynamic and steady-state methods for determining soil gas permeability assume that the soil is uncemented and uniform, with no preferential pathways for air flow. Conditions encountered at Area H did not match these modeling conditions.

1.3.3 Oxygen Influence

The depth and radius of oxygen influence in the subsurface resulting from air injection into the central VW during pilot testing is the primary design parameter for full-scale bioventing systems. Optimization of full-scale and multiple VW systems requires pilot testing to determine the volume of soil that can be oxygenated at a given flow rate and VW screen configuration.

Table 1.4 describes the change in soil gas oxygen levels that occurred during the 26-hour air injection test at the site. This relatively brief air injection period at 19 acfm produced changes in soil gas oxygen levels at a distance of at least 25.7 feet from the central VW at both points from which soil gas samples could be collected. It cannot be determined if the entire thickness of the vadose zone is being oxygenated, because soil gas samples could not be collected from seven of the nine MP screens during permeability testing.

1.3.4 In Situ Respiration Rates

In situ respiration testing was performed at Area H by injecting air (oxygen) and approximately 2 percent helium (inert tracer gas) into three MP screened intervals (VW, MPA-6, and MPC-12.4) for 39 hours at a rate of approximately 1 acfm per screened interval to deliver oxygen to contaminated soils. At the end of the 39-hour period, air injection ceased, and changes in soil gas composition were monitored over time. Oxygen, TVH, carbon dioxide, and helium were measured for a period of 72 hours following the air injection period. The observed rates of oxygen utilization were then used to estimate the aerobic fuel degradation rates at Area H. Figures 1.6 through 1.8 present the results of *in situ* respiration testing at the site, and Table 1.5 provides a summary of the observed oxygen utilization rates. Figure 1.9 presents the results of soil gas monitoring at the background soil gas probe HI-BG.

Because helium is a conservative, inert gas, the change in helium concentrations over time can be useful in determining if oxygen diffusion is responsible for a portion of the oxygen lost from each MP, or if leakage is occurring due to improper MP construction. Figures 1.6 through 1.8 compare oxygen utilization and helium retention at the three points used for respiration testing at Area H. Helium levels rose slightly during the test, while oxygen concentration declined rapidly with time. The rise in helium concentrations could be caused by helium diffusion toward each MP. Because there was no helium loss, and because helium will diffuse

TABLE 1.4
AREA H
INFLUENCE OF AIR INJECTION AT VENT WELL
ON MONITORING POINT OXYGEN LEVELS
HICKAM AFB, HAWAII

MP	Distance From VW (ft)	Depth(ft)	Initial O ₂ (%) ^{a/}	Final O ₂ (%) ^{b/}
A	6	6	0.0	8.7
C	25.7	12.4	1.1	4.2

a/ Initial O₂ samples collected prior to air permeability test and following the respiration test.
b/ Duration of air injection = 26 hours.

Figure 1.6
Respiration Test
Oxygen and Helium Concentrations
Area H
VW
Hickam AFB, HI

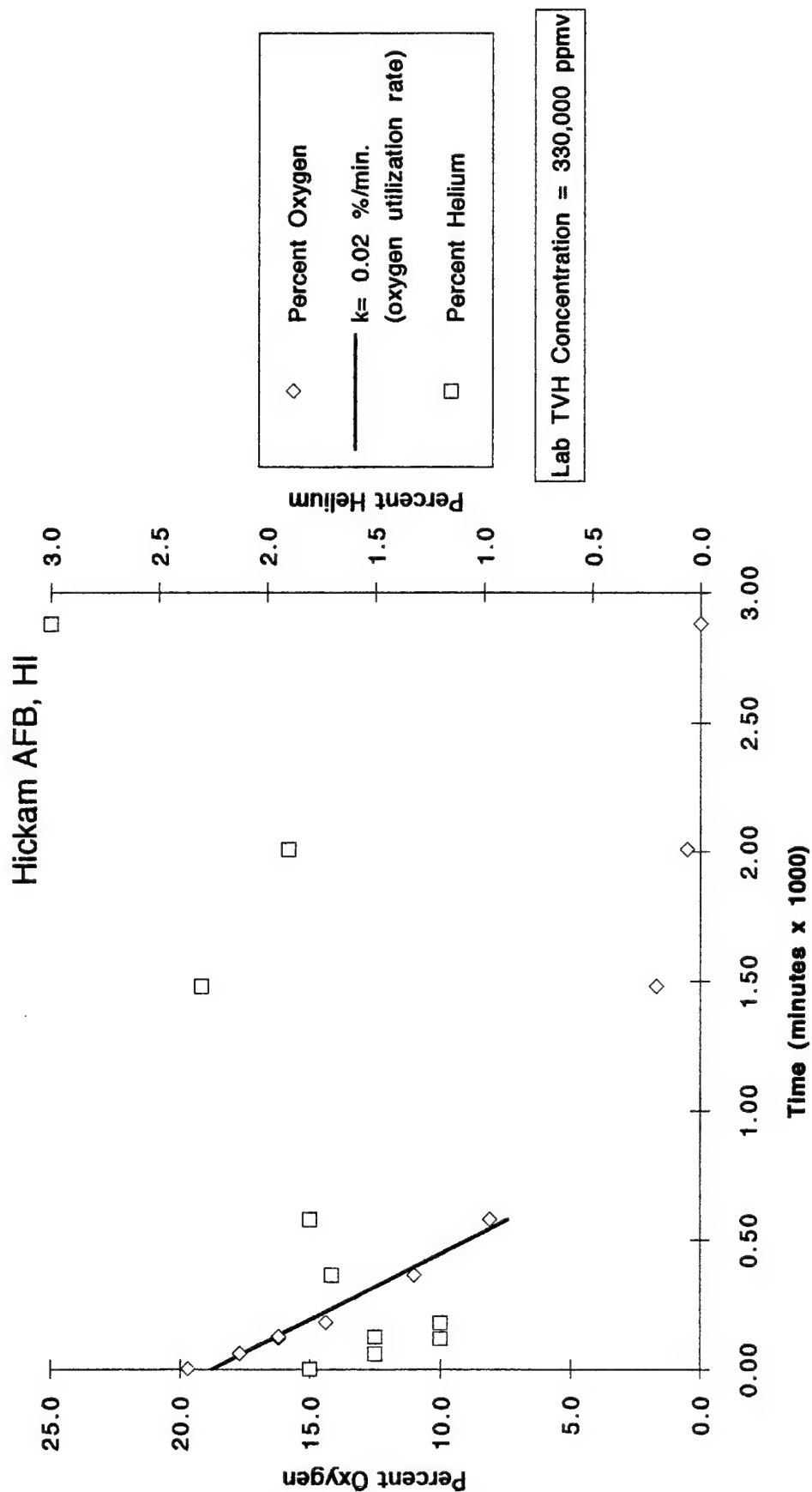


Figure 1.7
Respiration Test
Oxygen and Helium Concentrations
Area H
MPA-6
Hickam AFB, HI

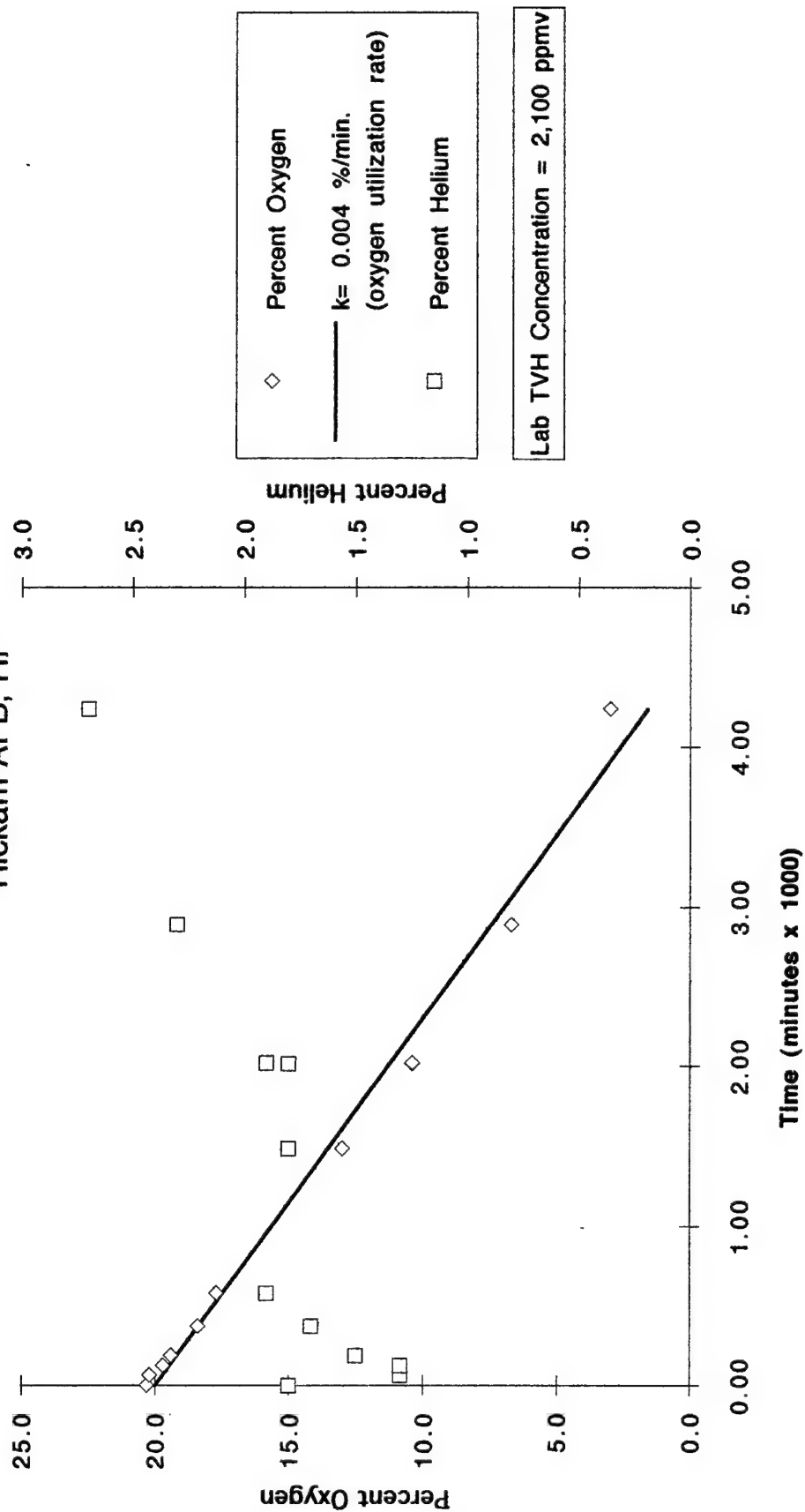


Figure 1.8
Respiration Test
Oxygen and Helium Concentrations
Area H
MPC-12.4
Hickam AFB, HI

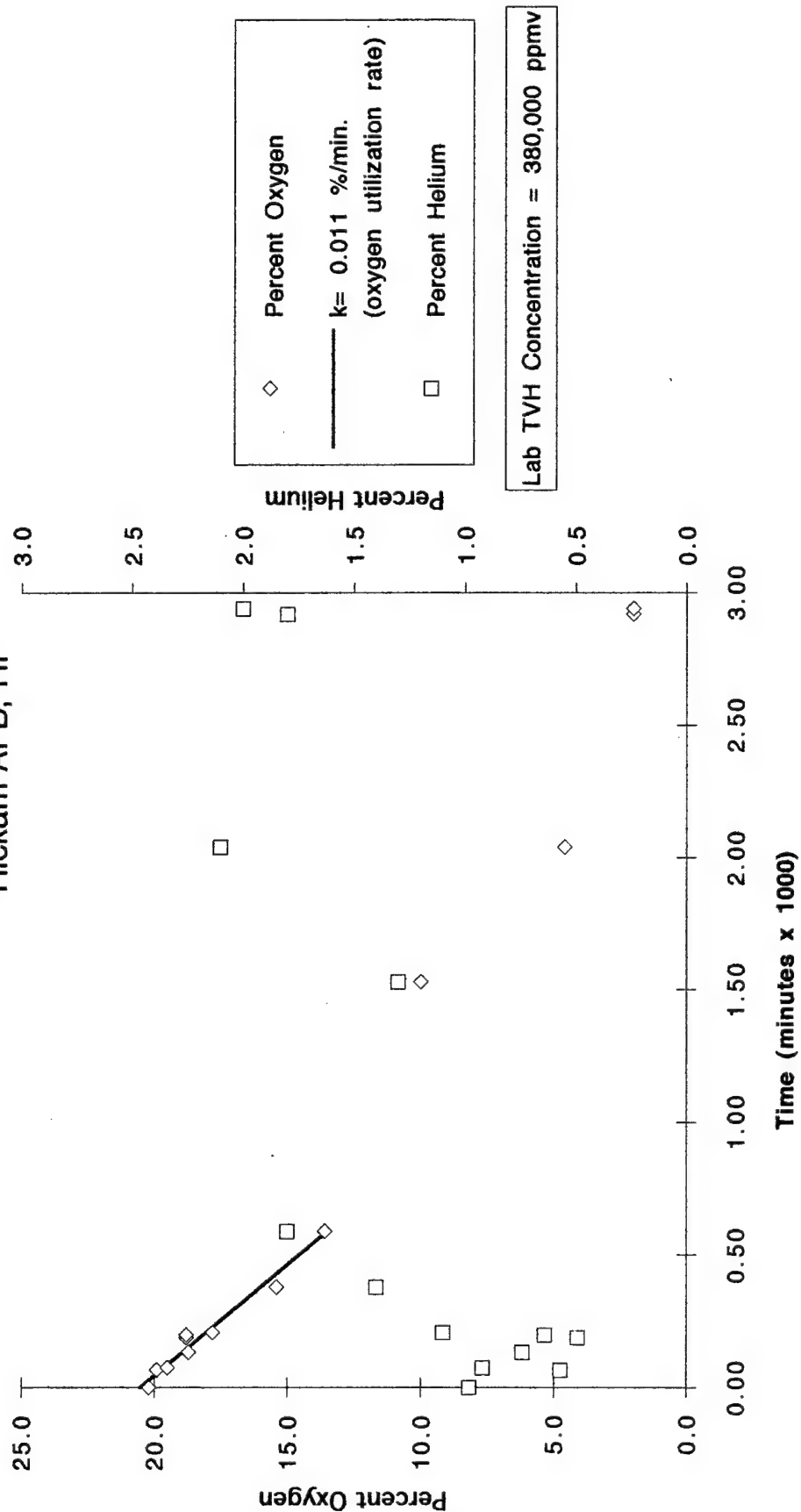
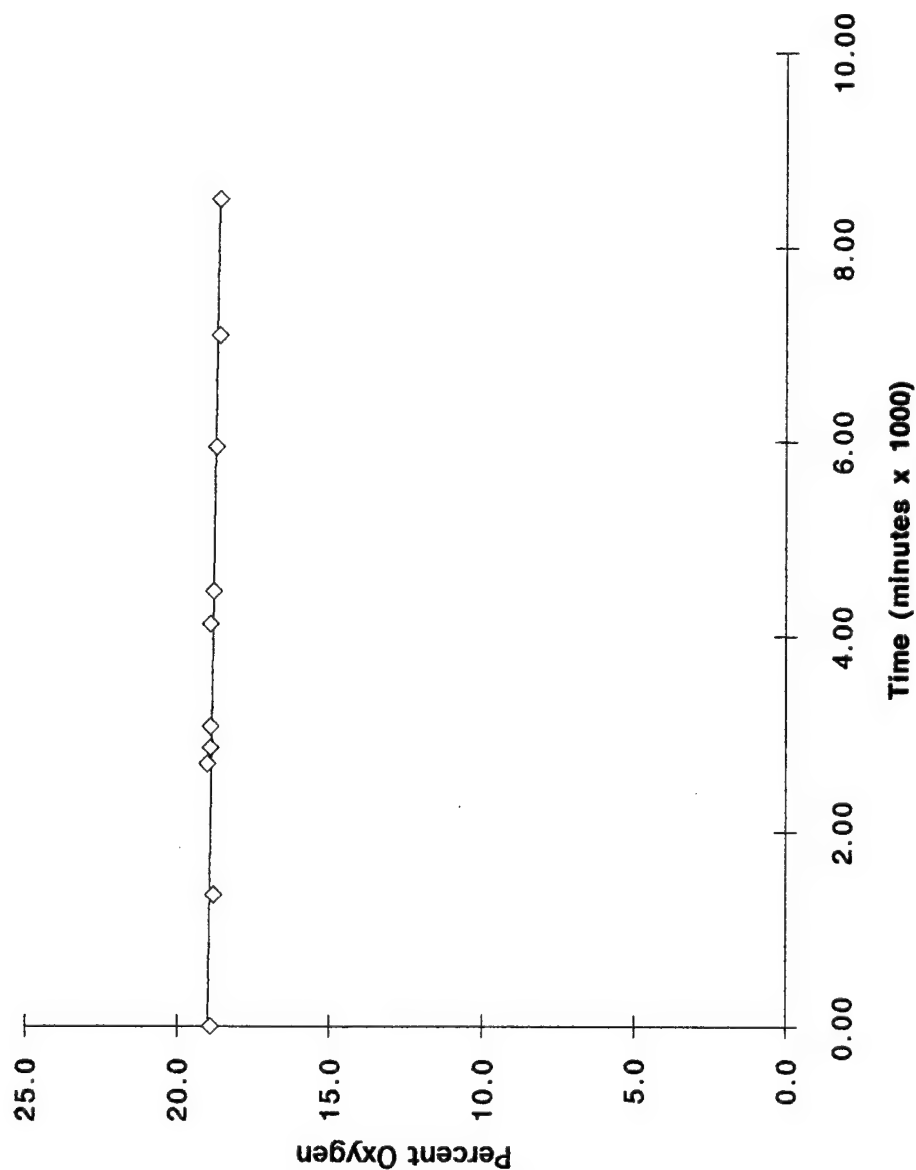


Figure 1.9
Oxygen Concentrations at BG Soil Gas Probe HI-BG
Hickam AFB, HI



Field TVH Concentration = 140 ppmv

TABLE 1.5
AREA H
OXYGEN UTILIZATION RATES
HICKAM AFB, HAWAII

MP	O ₂ Loss (%)	Test Duration (min)	O ₂ Utilization ^{a/} Rate (%/min)	Lab TVH Concentration (ppmv)
VW	11.6	580	0.020	330,000
MPA-6	17.3	4,235	0.004	2,100
MPC-12.4	6.6	590	0.011	380,000
HI-BG	0.3	8,495	0.00004	140 ^{b/}

a/ Values based on linear regression (Figures 1.6 through 1.8).
b/ Field TVH concentration.

approximately three times faster than oxygen, the measured oxygen loss can be attributed to bacterial respiration rather than diffusion or faulty MP construction.

Oxygen concentrations were monitored over time at background soil gas probe HI-BG to quantify respiration rates in uncontaminated soil (Figure 1.9). No air or helium injection was conducted at HI-BG. A comparison of the oxygen utilization rate at HI-BG [0.00004 percent per minute (%/min)] with the average of the oxygen utilization rates at the VW, MPA-6, and MPC-12.4 (0.012 %/min) demonstrates that the oxygen is being utilized by soil bacteria at Area H for the biodegradation of petroleum hydrocarbons rather than the consumption of naturally occurring soil organic matter.

At Area H, an estimated 100 milligrams (mg) of fuel per kilogram (kg) of soil can be degraded each year. This value is the average of the fuel consumption rates calculated for every point at which a respiration test was conducted. The MP-specific fuel consumption rates were calculated using observed oxygen utilization rates, estimated air-filled porosities, and a conservative ratio of 3.5 mg of oxygen consumed for every 1 mg of fuel biodegraded. The air-filled porosity, calculated for each sampling point, ranged from 0 to 0.026 liter of air per kg of soil. Actual air-filled porosities will be much greater than these values if significant fracture or seam zones exist in the formation. Thus, the calculated biodegradation rates for Area H are conservative.

Oxygen loss was rapid and linear at every MP during the early stages of the respiration test. Oxygen utilization rates observed at Area H ranged from 0.004 to 0.02 %/min (Table 1.5). The oxygen utilization rates observed at the VW and MPC-12.4 were an order of magnitude higher than that observed at MP-6. The difference in oxygen utilization rates is likely caused by differing contaminant concentrations at each location. At MPA-6, the laboratory TVH concentration was 2,100 ppmv, while the VW and MPC-12.4 yielded laboratory TVH concentrations of 330,000 and 380,000 ppmv, respectively. Because there is less fuel available for consumption at MPA-6, the local bacterial population is smaller, resulting in a lower oxygen utilization rate.

At the VW and MPC-12.4, the oxygen utilization rates appear to decrease over time (Figures 1.6 and 1.8). This apparent decrease has been observed at other shallow fuel spill sites, where an oxygen source is in close proximity to contaminated soils. Although much of the rock in the vadose zone seems to be highly impermeable, atmospheric oxygen could diffuse into the subsurface through fractures in the rock. As oxygen is rapidly consumed by fuel-degrading bacteria in deeper contaminated soils, the oxygen diffusion gradient between the contaminated soil and the atmosphere becomes substantial. As a result, oxygen begins to diffuse from the atmosphere into the contaminated soils. This inward oxygen diffusion temporarily masks the actual bacterial oxygen uptake rates. Because fuel biodegradation generally consumes oxygen at a rate that exceeds diffusion, the oxygen concentrations soon return to zero in contaminated soils.

1.3.5 Potential Air Emissions

Ambient air quality monitoring was conducted during the air permeability test to determine if air injection would displace VOCs into the atmosphere. Air quality monitoring was conducted using a hydrocarbon analyzer during the initial 8 hours of air injection at a flow rate of 19 acfm. Monitoring took place at eight locations on

Area H in an attempt to identify potential locations of VOC emissions from the soil. During this ambient air sampling program at Area H, no detections of VOCs occurred over the 1 ppmv detection limit of the instrument. Therefore, the bioventing system is operating at a flow rate low enough to avoid driving petroleum vapors into the atmosphere.

Neither benzene nor toluene were detected in laboratory soil gas samples collected from Area H (Table 1.1), indicating the long-term potential for emission of these potentially harmful VOCs into ambient air is minimal.

1.4 RECOMMENDATIONS

Initial bioventing tests at this site indicate that oxygen had been depleted in the contaminated soils, and that air injection is an effective method of stimulating aerobic fuel biodegradation. AFCEE has recommended that air injection continue at this site to determine the long-term radius of oxygen influence and the effect of time, available nutrients, and changing temperatures on fuel biodegradation rates.

A 1.5-horsepower rotary-vane blower has been installed at the site for continuous air injection. In November 1993, ES will return to the site to sample and analyze the soil gas and conduct a repeat respiration test. In April 1994, a final respiration test will be conducted, and soil and soil gas samples will be collected from the site to determine the degree of remediation achieved during the first year of *in situ* treatment. It is important to note that without some form of free product removal, soils will be subject to recontamination as groundwater levels fluctuate.

Based on the results of the first year of pilot-scale bioventing, AFCEE will recommend one of three options:

1. Upgrade the pilot-scale system, if necessary, and continue operation of the bioventing system for full-scale remediation of the site. Evaluate the need for integrating bioventing with free product recovery. AFCEE can assist the base in obtaining regulatory approval for upgrading and continued operation.
2. If final soil sampling indicates significant contaminant removal has occurred, AFCEE may recommend additional sampling to confirm that cleanup criteria have been achieved. However, it is very unlikely that cleanup criteria will be met until the free product is recovered from Area H.
3. If significant difficulties or poor results are encountered during bioventing at this site, AFCEE may recommend removal of the blower system and proper abandonment of the VW and MPs.

2.0 AREA K

2.1 Pilot Test Design and Construction

Installation of an air injection VW and three MPs at Area K took place on March 24 and 25, 1993. Drilling services were provided by Geolabs-Hawaii, Inc., of Honolulu, Hawaii. Well installation and soil sampling were directed by Mr. John Ratz, the ES site manager, and Mr. Craig Miller, the ES site geologist. The following sections describe the final design and installation of the bioventing system at this site.

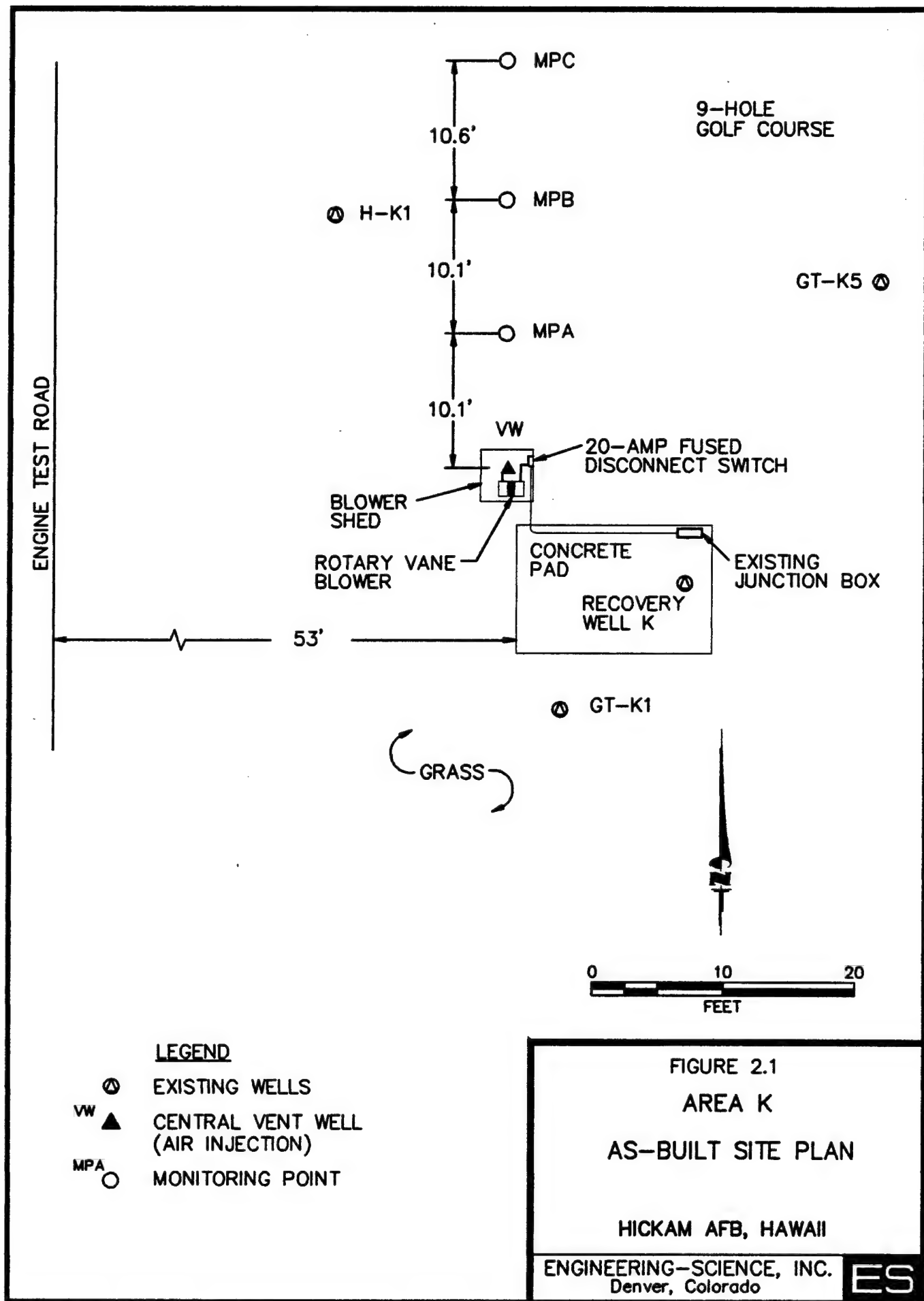
One VW, three MPs (MPA, MPB, and MPC), and a blower unit were installed at Area K. Figures 2.1 and 2.2, respectively, depict the locations of and a hydrogeologic cross section for the VW and MPs completed at Area K. Due to the large extent of contamination at Area K, no suitable locations for a background well were found. To characterize soil gas in uncontaminated soils at Hickam AFB, a soil gas probe was driven to a depth of 4.5 feet bgs at a location 3 feet west of existing groundwater monitoring well BKG-MW-29. BKG-MW-29 was installed at approximately the corner of Ohana Nui Circle and Puakala Street, in a residential area on the eastern side of Hickam AFB.

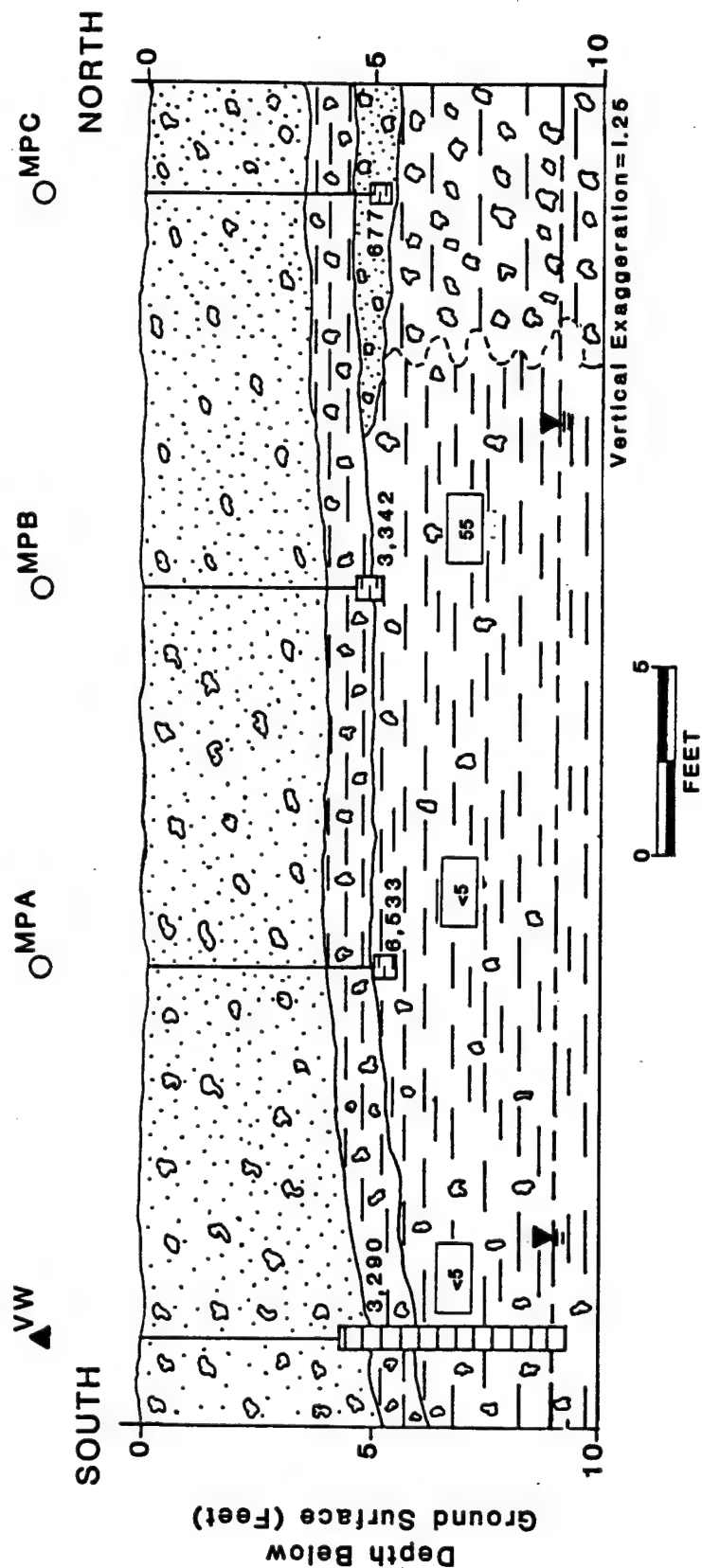
2.1.1 Air Injection Vent Well

The air injection VW was installed following procedures described in the AFCEE bioventing protocol document (Hinchee et al., 1992). Figure 2.3 shows construction details for the VW. The VW was installed in soil that contained hydrocarbon contamination at depths below 4.5 feet bgs. Groundwater was encountered at a depth of 9 feet bgs. The VW was constructed using 4-inch-diameter, Schedule 40 PVC casing, with 5 feet of 0.02-inch slotted PVC screen installed from 4.3 to 9.3 feet bgs. The annular space between the well casing and borehole was filled with number 3 silica sand from the bottom of the borehole to approximately 1.3 feet above the well screen. Approximately 2 feet of bentonite pellets were placed above the sand in 6-inch lifts, with each lift being hydrated in place. On top of the bentonite layer, approximately 1 foot of cement grout was placed and was finished flush with the ground surface. The well casing was cut off several inches above the surface, and the casing was connected to a galvanized steel header using a rubber pipe coupler.

2.1.2 Monitoring Points

At Area K, the three MPs (MPA, MPB, and MPC) were constructed as shown in Figure 2.4. A single screen was installed at each MP at 5 feet bgs. Each MP was constructed using a 6-inch section of 1-inch-diameter PVC well screen and a 0.25-inch-diameter PVC riser pipe extending to the ground surface. At the top of each riser, a ball valve and a 3/16-inch hose barb were installed. The top of each MP was





LITHOLOGIC DESCRIPTION

	CORALLINE RUBBLESTONE AND CORAL SAND		CLAY WITH RUBBLESTONE
	CLAY AND CORAL		CORAL WITH CLAY

LEGEND

MPA ○	MONITORING POINT		GROUNDWATER ELEVATION
VW ▲	INJECTION VENT WELL		GEOLOGIC CONTACT, DASHED WHERE INFERRED
677	FIELD SCREENING RESULTS FOR TOTAL VOLATILE HYDROCARBONS (ppmv)		MONITORING POINT
	LABORATORY RESULTS FOR SOIL TOTAL PETROLEUM HYDROCARBONS (mg/kg)		SCREENED WELL INTERVAL

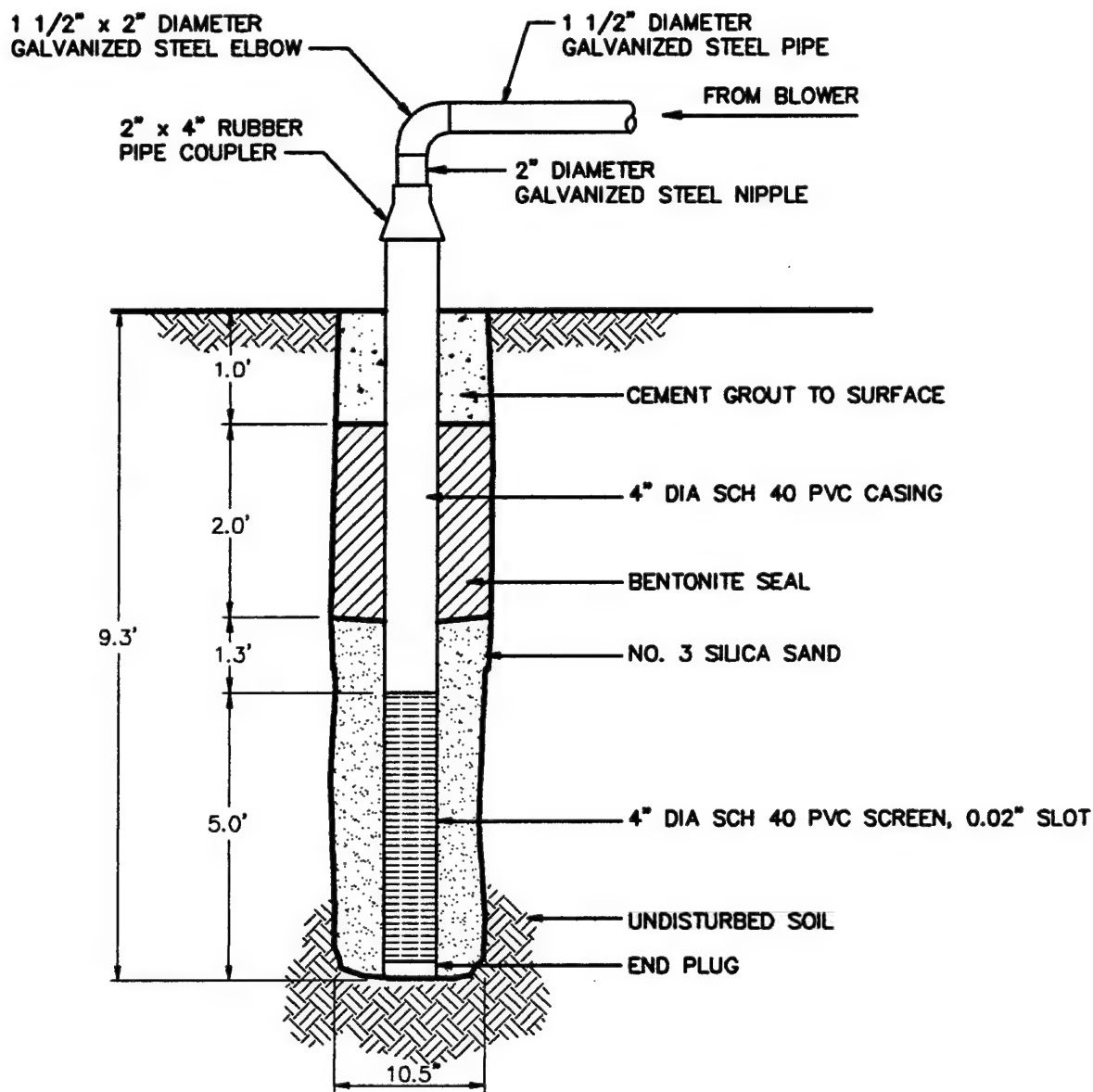
FIGURE 2.2

AREA K HYDROGEOLOGIC CROSS SECTION

HICKAM AFB, HAWAII

ENGINEERING-SCIENCE, INC.
Denver, Colorado

ES



NOT TO SCALE

FIGURE 2.3

AREA K
AS-BUILT INJECTION VENT WELL
CONSTRUCTION DETAIL

HICKAM AFB, HAWAII

ENGINEERING-SCIENCE, INC.
Denver, Colorado

ES

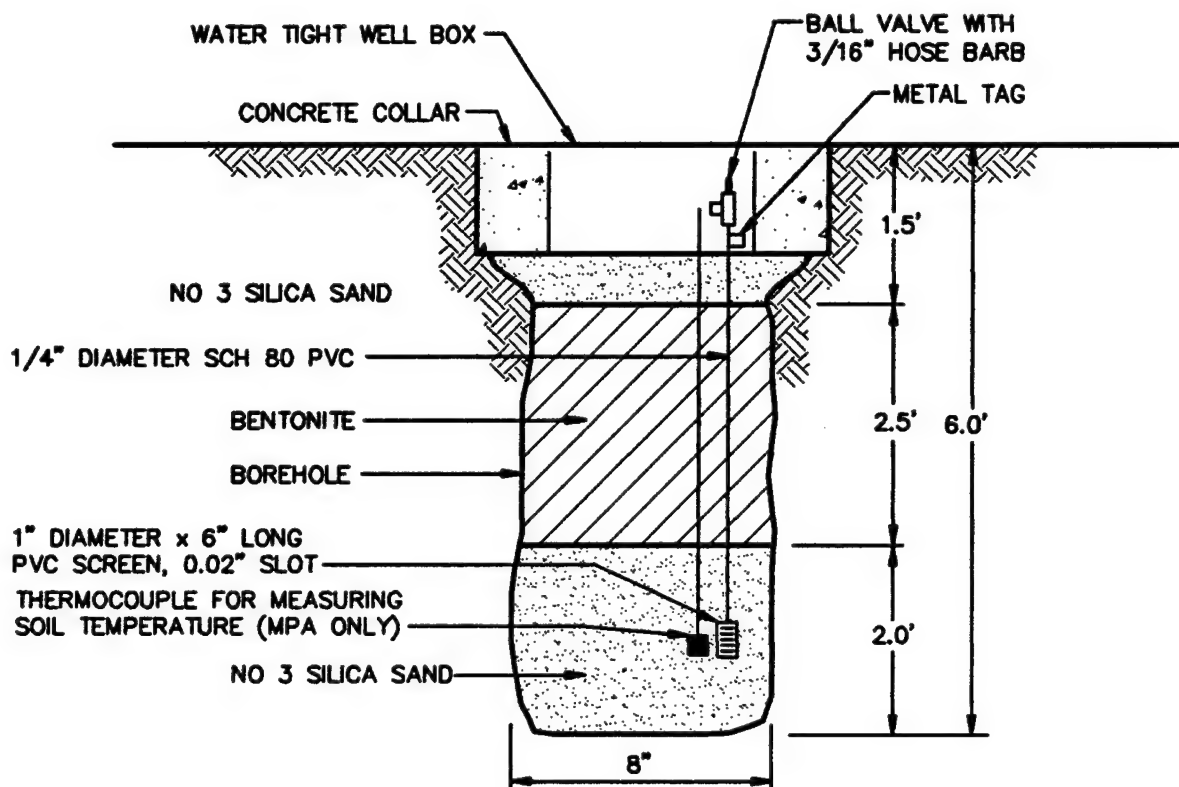


FIGURE 2.4

AREA K
AS-BUILT MONITORING POINT
CONSTRUCTION DETAIL

HICKAM AFB, HAWAII

ENGINEERING-SCIENCE, INC.
Denver, Colorado

ES

completed with a flush-mounted metal well protector set in a concrete base. A thermocouple was installed at the 5-foot depth at MPA to measure soil temperature variations.

2.1.3 Blower Unit

For both the initial and extended pilot tests, a 1.5-horsepower Gast® model 2567-P102 rotary-vane blower unit was used. During the initial air permeability test, the unit was energized by 230-volt, single-phase, 20-amp power from a temporary exterior receptacle. The fixed unit is energized by 230-volt, single-phase, 20-amp line power from an existing junction box formerly used to supply power to product recovery equipment. Hickam AFB electricians performed the electrical installation. The configuration and instrumentation for this system are shown in Figure 2.5. The blower is currently transporting air at a flow rate of approximately 20 acfm for the extended pilot test. After blower installation and startup, ES engineers provided an O&M manual, including maintenance instructions, equipment specifications and monitoring forms, to base personnel. A copy of the O&M instructions is provided in Appendix A.

2.2 PILOT TEST SOIL AND SOIL GAS SAMPLING RESULTS

2.2.1 Sampling Results

Vadose zone soils at Area K generally consist of two layers. From the surface to approximately 5 feet bgs, soils consist of coralline rubblestone and coral sand. Below 5 feet bgs, the soils are composed of coralline rubblestone and clay, with the clay content generally increasing with depth. Groundwater was encountered at a depth of approximately 9.0 feet bgs in the VW. A free product sheen was detected on top of the groundwater in the VW. More detailed hydrogeologic information regarding Area K may be found in the hydrogeologic cross section (Figure 2.2) and the geologic boring logs (Appendix B).

Contaminated soils were identified based on visual appearance, odor, and VOC field screening results. Heavily contaminated soils were encountered below 4.5 feet bgs at the VW and each MP borehole. Soils at these locations had a strong hydrocarbon odor, and field VOC headspace concentrations ranged from 677 to 6,533 ppmv.

Soil samples for laboratory analysis were collected from 18-inch split-spoon samplers with 2-inch-diameter brass liners. Soil samples were screened for VOCs using a hydrocarbon analyzer to determine the presence of contamination and to select soil samples for laboratory analysis. Soil samples for laboratory analysis were collected from MPA at a depth of 5.5 feet bgs, from MPB at a depth of 5.5 feet bgs, and from the VW at a depth of 6.5 feet bgs.

Soil gas samples were collected from the completed VW, MPA, and MPC. Soil gas samples were collected using 3-liter Tedlar® bags and vacuum chambers. After the samples were collected in the Tedlar® bags, they were transferred into 1-liter SUMMA® canisters and shipped to the laboratory.

LEGEND

- ① INLET AIR FILTER- GAST® MODEL AA 905G
- ② 1 1/2 HORSEPOWER ROTARY VANE BLOWER-
GAST® MODEL 2567-P102
- ③ AUTOMATIC PRESSURE RELIEF VALVE-
GAST® MODEL AA307
- ④ MANUAL PRESSURE RELIEF (BLEED) VALVE- 3/4" GATE
- ⑤ TEMPERATURE GAUGE (0-250° F)
- ⑥ PRESSURE GAUGE (0-100 IN H₂O)
- ⑦ DISCONNECT SWITCH- 230V/SINGLE PHASE/20 AMP

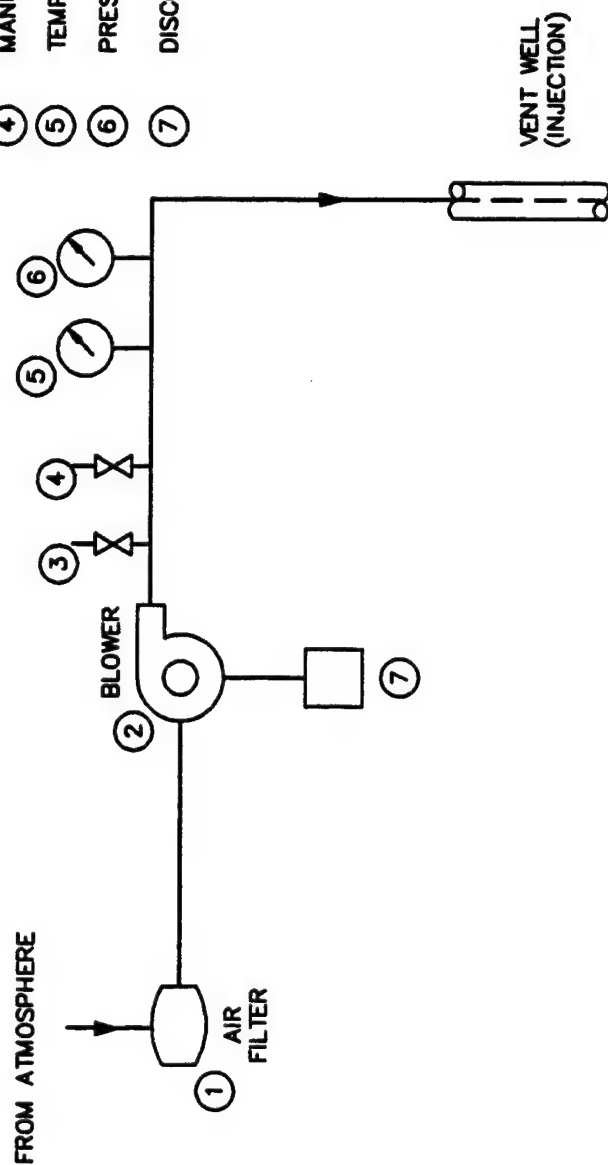


FIGURE 2.5

AREA K AS-BUILT BLOWER SYSTEM FOR AIR INJECTION

HICKAM AFB, HAWAII

ENGINEERING-SCIENCE, INC.
Denver, Colorado

ES

Soil samples were shipped to the Pace, Inc. laboratory in Novato, California, for chemical and physical analysis. Soil samples were analyzed for TRPH, BTEX, iron, alkalinity, TKN, and several physical parameters. Soil gas samples were shipped to Air Toxics, Inc. in Rancho Cordova, California, for TVH and BTEX analysis. TVH analyses were referenced to JP-4 jet fuel. The results of these analyses are provided in Table 2.1. Chain-of-custody forms are provided in Appendix B.

2.2.2 Exceptions To Test Protocol Procedures

Procedures described in the protocol document (Hinchee et al., 1992) were used to complete treatability tests at Area K, with the following exception. Due to the widespread extent of fuel contamination, there were no suitable locations to install a background MP at Area K. Therefore, soil gas probe HI-BG was installed to provide background soil gas data for Area K.

2.3 PILOT TEST RESULTS

2.3.1 Initial Soil Gas Chemistry

Prior to initiating any air injection, all MPs and the VW were purged, and initial oxygen, carbon dioxide, and TVH concentrations were determined using portable gas analyzers, as described in the technical protocol document (Hinchee et al., 1992). Table 2.2 summarizes the initial soil gas chemistry at Area K. The results strongly indicate that biological fuel degradation is occurring in vadose zone soils at Area K.

MPA was under anaerobic conditions, and soil gas from MPB and MPC contained oxygen at low levels of 2.5 and 6.3 percent, respectively. In contrast, soil gas probe HI-BG, installed in uncontaminated soils near existing monitoring well BKG-MW-29, contained oxygen at a concentration of 18.9 percent during initial sampling. Carbon dioxide was present at elevated concentrations, ranging from 9.4 to 13.6 percent, in soil gas samples collected from the MPs. The background MP carbon dioxide concentration was 3.5 percent. Because the fuel-contaminated soil gas at Area K contains low oxygen and high carbon dioxide concentrations relative to uncontaminated background soil gas, oxygen consumption and carbon dioxide accumulation in soil gas at Area K can be attributed to petroleum hydrocarbon biodegradation rather than the consumption of naturally occurring soil organic matter.

The VW at Area K yielded initial soil gas results that were uncharacteristic of fuel-contaminated soils. Oxygen was present at the VW at a concentration of 17.3 percent, and carbon dioxide, field TVH, and lab TVH concentrations were low relative to the concentrations measured at the MPs. Soil gas from uncontaminated soils above the "smear zone" was likely pulled into the VW during purging. The VW was purged at 1 acfm for 20 minutes, due to the large volume of the VW. In contrast, each MP was purged for only 1 minute prior to sampling. The soil from 0 to 5 feet bgs at the VW is highly permeable, and soil gas probably flowed

TABLE 2.1
AREA K
SOIL AND SOIL GAS ANALYTICAL RESULTS
HICKAM AFB, HAWAII

Analyte (Units) ^{a/}	Sample Location-Depth (feet below ground surface)		
<u>Soil Hydrocarbons</u>	<u>VW-6.5</u>	<u>MPA-5.5</u>	<u>MPB-5.5</u>
TRPH (mg/kg)	ND ^{b/}	ND	55
Benzene (mg/kg)	0.54	ND	2.2
Toluene (mg/kg)	5.9	6.5	23
Ethylbenzene (mg/kg)	2.6	6.4	21
Xylenes (mg/kg)	13.0	12	32
<u>Soil Gas Hydrocarbons</u>	<u>VW</u>	<u>MPA-5</u>	<u>MPC-5</u>
TVH (ppmv)	4,000	41,000	34,000
Benzene (ppmv)	3.5	130	120
Toluene (ppmv)	ND	ND	ND
Ethylbenzene (ppmv)	2.7	41	22
Xylenes (ppmv)	14	81	48
<u>Soil Inorganics</u>	<u>VW-6.5</u>	<u>MPA-5.5</u>	<u>MPB-5.5</u>
Iron (mg/kg)	75,900	2,840	23,500
Alkalinity (mg/kg as CaCO ₃)	1,200	540	830
pH (units)	8.5	8.4	8.1
TKN (mg/kg)	110	3,100	2,000
Phosphates (mg/kg)	190	1,700	5,000
<u>Soil Physical Parameters</u>	<u>VW-6.5</u>	<u>MPA-5.5</u>	<u>MPB-5.5</u>
Moisture (% wt.)	15.1	15.9	15.4
Gravel (%)	14	30	63
Sand (%)	42	46	29
Silt (%)	15	13	4
Clay (%)	29	11	4
<u>Soil Temperature (°F)</u>	<u>MPA-5</u>		
	79.0		

- ^{a/} TRPH = total recoverable petroleum hydrocarbons; mg/kg = milligrams per kilogram;
TVH = total volatile hydrocarbons; ppmv = parts per million, volume per volume;
CaCO₃ = calcium carbonate; TKN = total Kjeldahl nitrogen, °F = degrees Fahrenheit.
- ^{b/} ND = not detected.

TABLE 2.2
AREA K
INITIAL SOIL GAS CHEMISTRY
HICKAM AFB, HAWAII

MP	Depth (ft)	O ₂ (%)	CO ₂ (%)	Field TVH (ppmv)	Lab TVH (ppmv)
VW	4.3-9.3	17.3	3.3	6,000	4,000
A	5.0	0.0	13.6	>20,000	41,000
B	5.0	2.5	12.0	>20,000	NS ^{a/}
C	5.0	6.3	9.4	>20,000	34,000
HI-BG	4.5	18.9	3.5	140	NS

a/ NS = not sampled

preferentially from these cleaner, shallow soils into the well screen during the purging event. Thus, soil gas data from the VW is believed to reflect average conditions in the shallow coralline rubblestone and sand layer, which contains no fuel contamination between 0 and 4.5 feet bgs. Data from the MPs more accurately reflect conditions in the fuel-contaminated soils.

Hydrocarbon concentrations at Area K were extremely high, possibly indicating the volatilization of fuel constituents from the free product layer into the pore space of the vadose zone soils at Area K.

2.3.2 Air Permeability

An air permeability test was conducted at Area K according to protocol document procedures. Air was injected into the VW for approximately 17.5 hours at a rate of approximately 20 acfm and an average pressure of approximately 2.4 psi. The pressure response at each MP is listed in Table 2.3. Using the steady-state method, a soil gas permeability value of 5.27 darcys was calculated for this site. A radius of pressure influence of at least 30 feet was observed at MPC.

2.3.3 Oxygen Influence

The depth and radius of oxygen influence in the subsurface resulting from air injection into the central VW during pilot testing is the primary design parameter for full-scale bioventing systems. Optimization of full-scale and multiple VW systems requires pilot testing to determine the volume of soil that can be oxygenated at a given flow rate and VW screen configuration.

Table 2.4 describes the change in soil gas oxygen levels that occurred during the 17.5-hour air injection test at the site. This air injection period at 20 acfm produced changes in soil gas oxygen levels at a distance of at least 30 feet from the central VW in the fuel-contaminated "smear zone". Significant increases in oxygen levels were measured at each MP. Based on measured pressure response, which is an indicator of long-term oxygen transport, it is anticipated that the radius of influence for a long-term bioventing system at this site will exceed 30 feet within the fuel-contaminated zone. Monitoring during the extended pilot test at this site will better define the effective treatment radius.

2.3.4 In Situ Respiration Rates

In situ respiration testing was performed at Area K by injecting air (oxygen) and approximately 2 percent helium (inert tracer gas) into each MP screen for 16.5 hours at a rate of approximately 1 acfm per screened interval to deliver oxygen to contaminated soils. At the end of the 16.5-hour period, air injection ceased and changes in soil gas composition were monitored. Oxygen, TVH, carbon dioxide, and helium concentrations were measured in soil gas samples collected over a period of 64 hours following the air injection period. The observed rates of oxygen utilization were then used to estimate the aerobic fuel degradation rates at Area K. Figures 2.6 through 2.9 present the results of *in situ* respiration testing at the site, and

TABLE 2.3
AREA K
PRESSURE RESPONSE DURING THE AIR PERMEABILITY TEST
HICKAM AFB, HAWAII

Distance from VW	Pressure Response In MP (inches of water)		
	MPA 10.1	MPB 20.2	MPC 30.8
Elapsed Time (min.)			
0.5	0.1	0.05	0.06
1.0	0.3	0.15	0.11
3.0	0.4	0.15	0.11
4.0	0.45	0.17	0.12
5.0	0.47	0.18	0.13
7.0	0.55	0.20	0.14
9.0	0.60	0.21	0.175
15.0	0.65	0.25	0.19
18.0	0.70	0.27	0.19
23.0	0.95	0.32	0.25
30.0	1.10	0.40	0.29
45.0	1.20	0.40	0.30
90.0	1.30	0.42	0.31
1050	1.65	0.50	0.35

TABLE 2.4
AREA K
INFLUENCE OF AIR INJECTION AT VENT WELL
ON MONITORING POINT OXYGEN LEVELS
HICKAM AFB, HAWAII

MP	Distance From VW (ft)	Depth(ft)	Initial O ₂ (%) ^{a/}	Final O ₂ (%) ^{b/}
A	10.1	5.0	0.0	18.3
B	20.2	5.0	4.0	14.7
C	30.8	5.0	2.0	6.8

a/ Initial O₂ samples collected prior to air permeability test and following the respiration test.
b/ Duration of air injection = 17.5 hours.

Figure 2.6
Respiration Test
Oxygen and Helium Concentrations
Area K
VW
Hickam AFB, HI

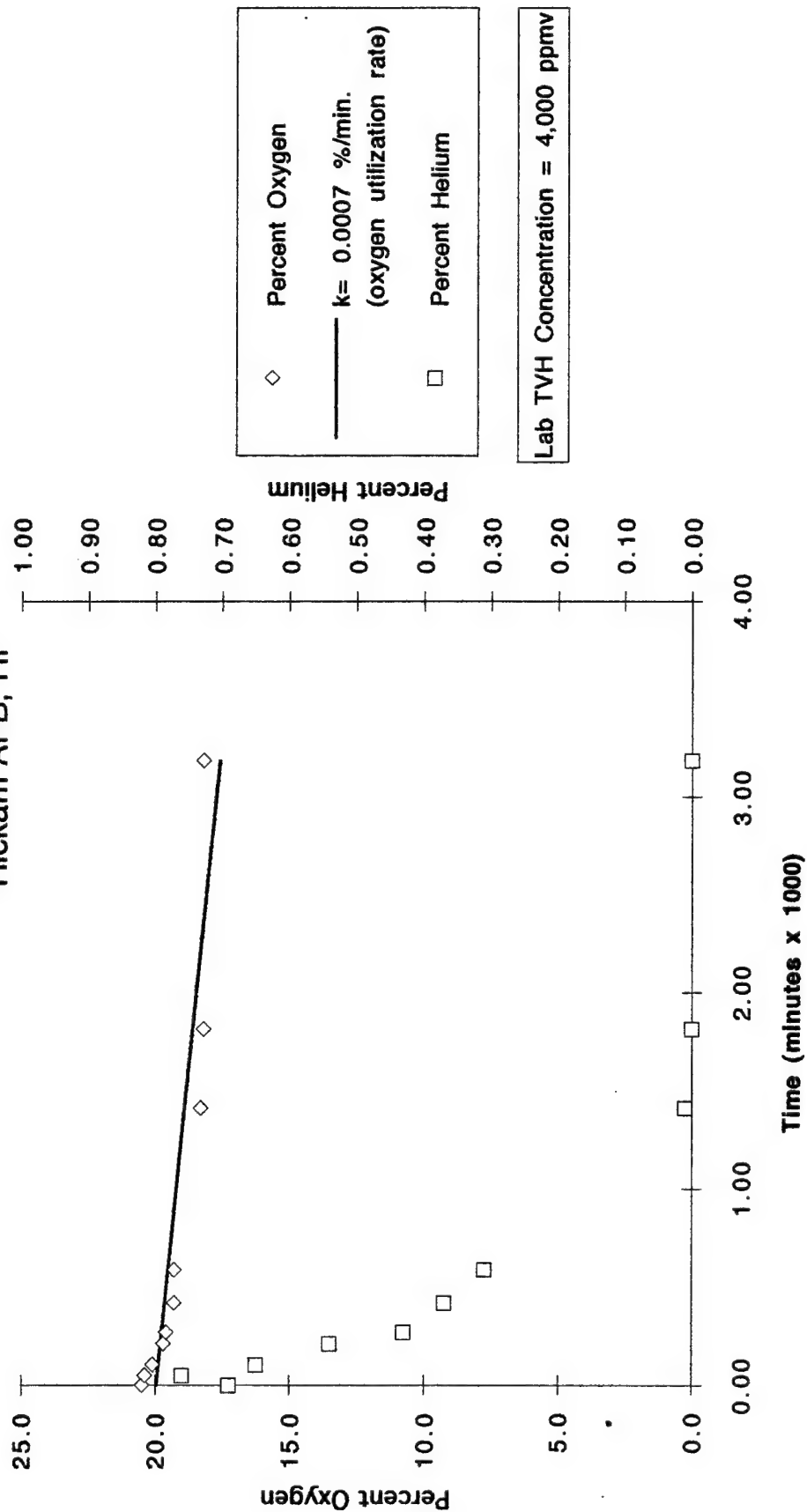


Figure 2.7
Respiration Test
Oxygen and Helium Concentrations
Area K
MPA
Hickam AFB, HI

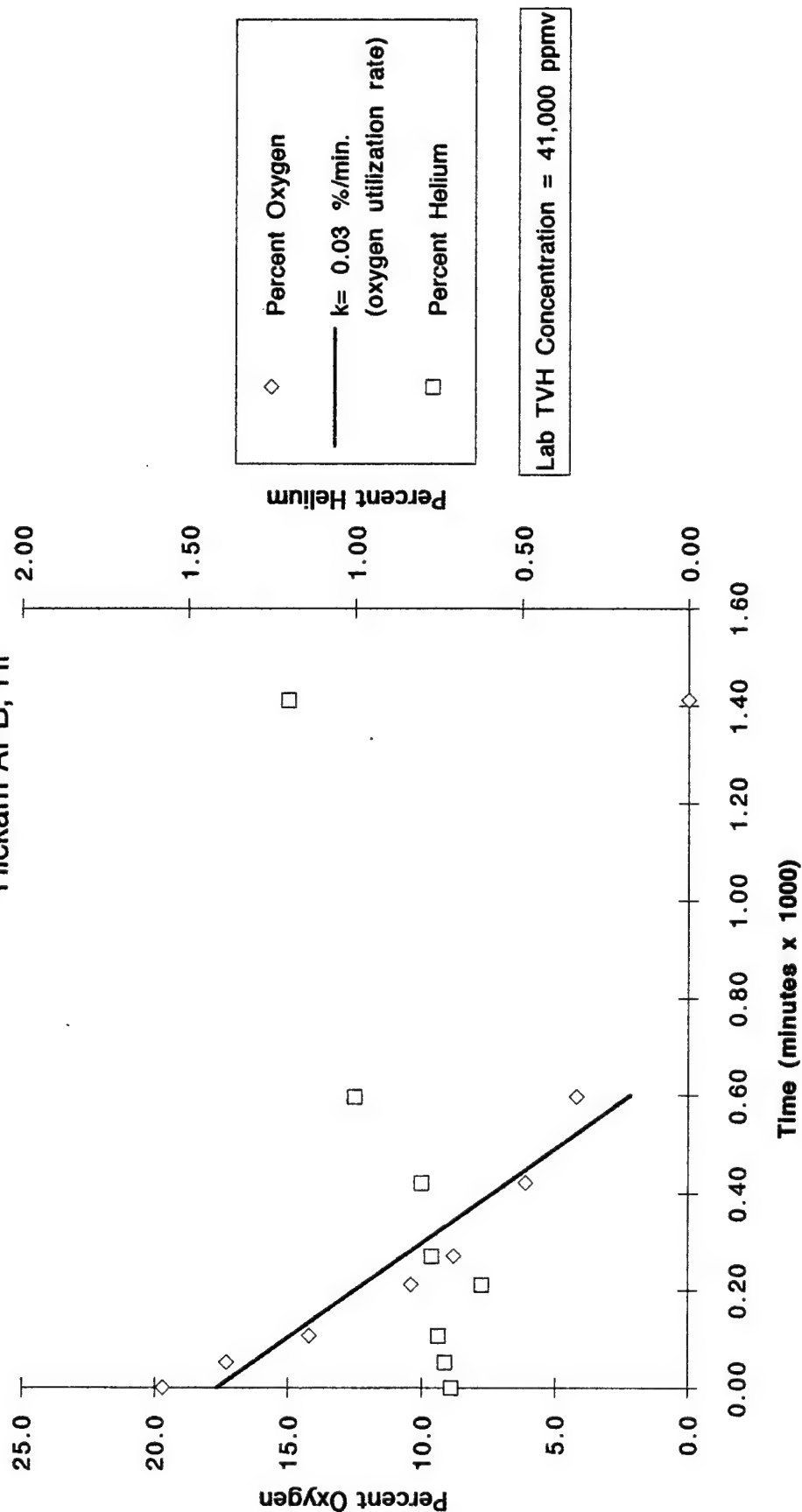


Figure 2.8
Respiration Test
Oxygen and Helium Concentrations
Area K
MPB
Hickam AFB, HI

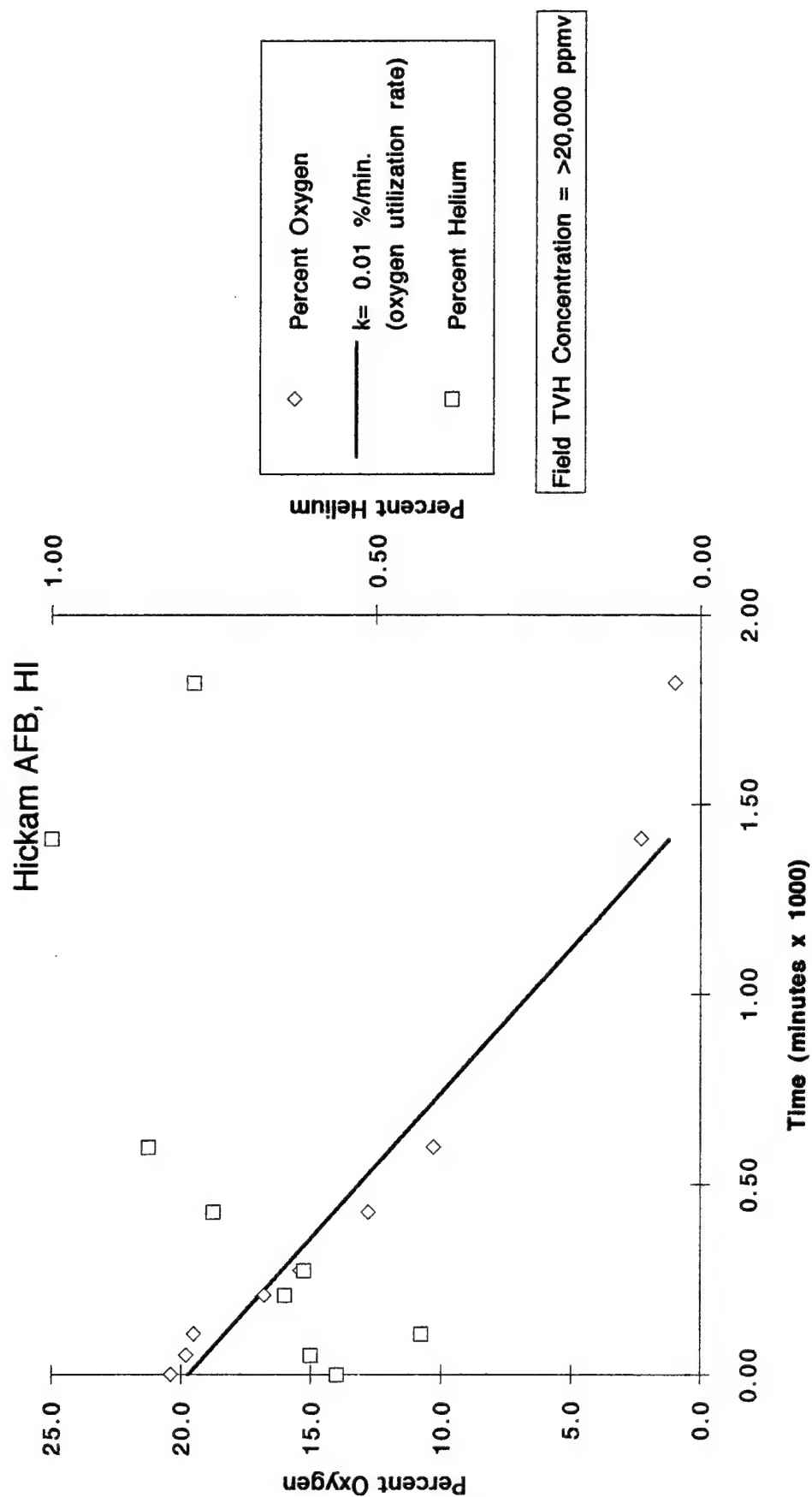


Figure 2.9
Respiration Test
Oxygen and Helium Concentrations
Area K
MPC
Hickam AFB, HI

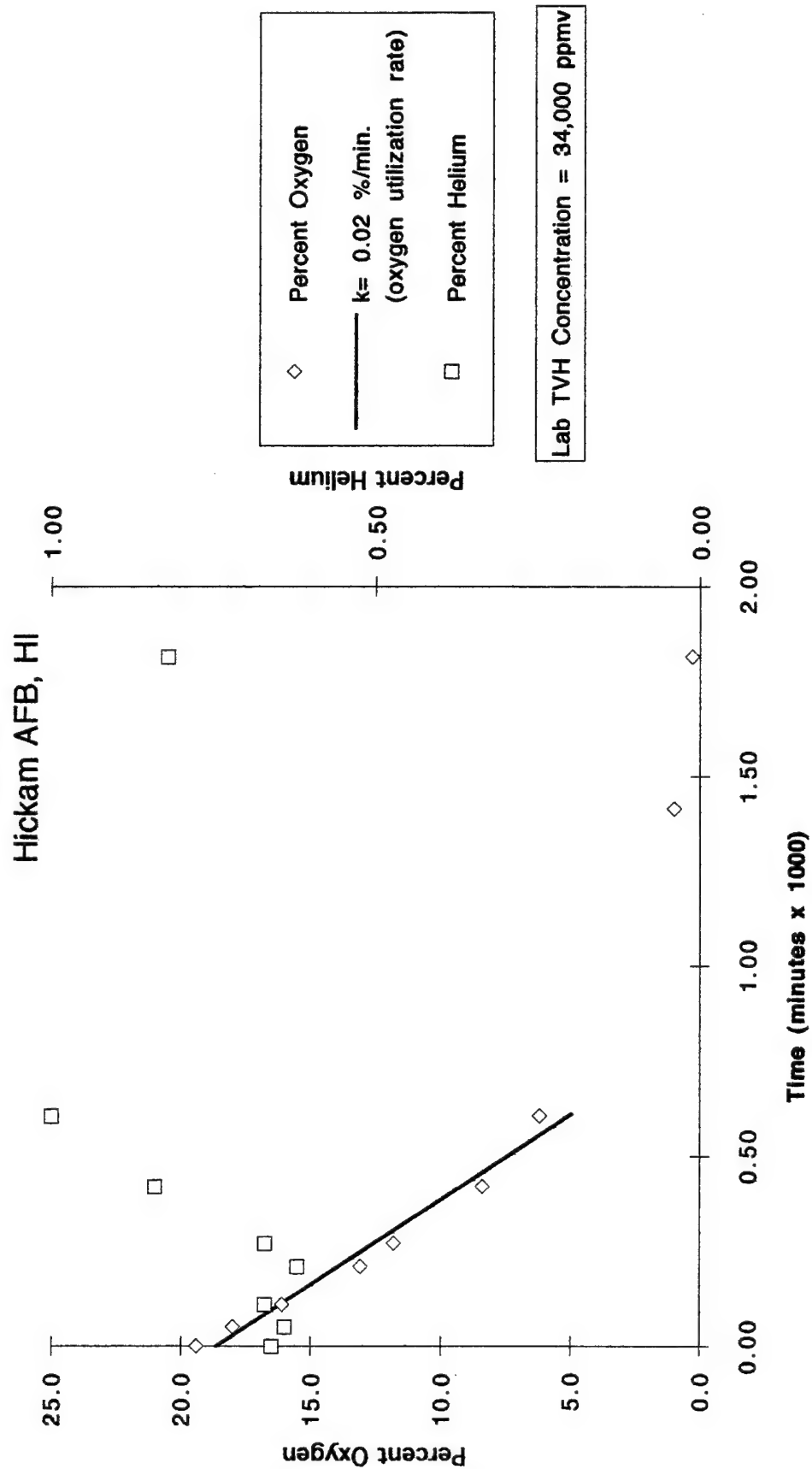


Table 2.5 provides a summary of the observed oxygen utilization rates. Figure 1.9 presents the results of soil gas monitoring conducted at the background soil gas probe HI-BG.

Because helium is a conservative, inert gas, the change in helium concentrations over time can be useful in determining if oxygen diffusion is responsible for a portion of the oxygen lost from each MP, or if leakage is occurring due to improper MP construction. Figures 2.7 through 2.9 compare oxygen utilization and helium retention at the MPs. At each MP, helium levels rose slightly during the test, while oxygen concentrations declined rapidly with time. It is possible that the helium concentration in the injected air/helium mixture dropped slightly over the 16.5-hour injection period, and the rise in helium concentrations in the soil gas could be caused by helium diffusion toward the MP screen. Because there was no helium loss, and because helium will diffuse approximately three times faster than oxygen, the measured oxygen loss at the MPs can be attributed to bacterial respiration rather than diffusion or faulty MP construction. At the VW, helium concentrations declined rapidly over time, while oxygen levels remained relatively constant (Figure 2.6). Because the soil at Area K from 0 to 5 feet bgs is highly permeable, and because the top of the VW screen is only 4.3 feet bgs, the helium loss can be attributed to short-circuiting. During each purging event, gas was apparently pulled from shallow, uncontaminated soils and the atmosphere into the well screen, causing helium loss and masking oxygen consumption in fuel-contaminated soils. Therefore, the oxygen utilization rate at the VW does not accurately reflect hydrocarbon consumption rates at Area K.

Oxygen concentrations were monitored over time at background soil gas probe HI-BG to quantify respiration rates in uncontaminated soil (Figure 1.9). No air or helium was injected into HI-BG. A comparison of the oxygen utilization rate at HI-BG (0.00004 %/min) with the average of the oxygen utilization rates at the MPs (0.02%/min) demonstrates that the oxygen is being utilized by soil bacteria at Area K for the biodegradation of petroleum hydrocarbons rather than the consumption of naturally occurring soil organic matter.

At Area K, an estimated 3,380 mg of fuel per kg of soil can be degraded each year. This value is based on the average of the fuel consumption rates calculated for each MP. The MP-specific fuel consumption rates were calculated using observed oxygen utilization rates, estimated air-filled porosities, and a conservative ratio of 3.5 mg of oxygen consumed for every 1 mg of fuel biodegraded. The air-filled porosity, calculated for each sampling point, ranged from 0.083 to 0.089 liter of air per kg of soil.

At MPA and MPC, the oxygen utilization rates appear to decrease over time (Figures 2.7 and 2.9). This apparent decrease has been observed at other shallow fuel spill sites where an oxygen source is in close proximity to contaminated soils. Vadose zone soil at Area K has a high sand and rock content, and therefore is highly permeable. As oxygen is rapidly consumed by fuel-degrading bacteria in deeper, contaminated soils, the oxygen diffusion gradient between the contaminated soil and the atmosphere becomes substantial. As a result, oxygen begins to diffuse from the atmosphere into the contaminated soils. This inward oxygen diffusion temporarily masks the actual bacterial oxygen uptake rates. Because fuel biodegradation generally consumes oxygen at a rate that exceeds diffusion, the oxygen concentrations soon return to zero in contaminated soils.

TABLE 2.5
AREA K
OXYGEN UTILIZATION RATES
HICKAM AFB, HAWAII

MP	O ₂ Loss (%)	Test Duration (min)	O ₂ Utilization ^{a/} Rate (%/min)	Lab TVH Concentration (ppmv)
VW	2.2	3,205	0.0007	4,000
MPA	15.5	590	0.026	41,000
MPB	18.1	1,410	0.013	>20,000 ^{b/}
MPC	13.2	605	0.022	34,000
HI-BG	0.3	8,495	0.00004	140 ^{b/}

^{a/} Values based on linear regression (Figures 2.6 through 2.9).
^{b/} Field TVH concentrations.

2.3.5 Potential Air Emissions

Ambient air quality monitoring was conducted during the air permeability test to determine if air injection would displace VOCs into the atmosphere. Air quality monitoring was conducted using a hydrocarbon analyzer during the initial 8 hours of air injection at a flow rate of 20 acfm. Monitoring took place at eight locations at Area K in an attempt to identify potential locations of VOC emissions from the soil. During this ambient air sampling program at Area K, VOCs were detected in ambient air at two locations. Near the 12-inch product recovery well K (Figure 2.1), VOCs were detected in ambient air at concentrations ranging from 1 to 8 ppmv. Injected air apparently was short-circuiting through the screen of this recovery well, which was open to the atmosphere during pilot testing. Near GT-K1 (Figure 2.1) VOCs were detected in ambient air at concentrations ranging from 1 to 4 ppmv. Again, it appeared that injected air was short-circuiting through the well screen of GT-K1 into the atmosphere. The well cap on GT-K1 was tightened, and a plastic cap was placed over recovery well K. After these actions were taken, no VOCs were detected in the ambient air during the remainder of the initial pilot test.

Benzene was detected in soil gas at Area K at concentrations ranging from 3.5 to 130 ppmv (Table 2.1). Toluene was not detected. Provided that all avenues for short-circuiting remain blocked, the long-term potential for emission of these compounds into ambient air is minimal.

2.4 RECOMMENDATIONS

Initial bioventing tests at this site indicate that oxygen has been depleted in the contaminated soils, and that air injection is an effective method of stimulating aerobic fuel biodegradation. AFCEE has recommended that air injection continue at this site to determine the long-term radius of oxygen influence and the effect of time, available nutrients, and changing temperatures on fuel biodegradation rates.

A 1.5-horsepower rotary-vane blower has been installed at the site for continuous air injection. In November 1993, ES will return to the site to sample and analyze the soil gas and conduct a repeat respiration test. In April 1994, a final respiration test will be conducted, and soil and soil gas samples will be collected from the site to determine the degree of remediation achieved during the first year of *in situ* treatment. At Area K, it is important to note that without some form of free product removal, vadose zone soils will be subject to recontamination as groundwater levels rise.

Based on the results of the first year of pilot-scale bioventing, AFCEE will recommend one of three options:

1. Upgrade, if necessary, and continue operation of the bioventing system for full-scale remediation of the site. AFCEE can assist the base in obtaining regulatory approval for upgrading and continued operation. Free product removal may also be required for full-scale remediation.

2. If final soil sampling indicates significant contaminant removal has occurred, AFCEE may recommend additional sampling to confirm that cleanup criteria have been achieved.
3. If significant difficulties or poor results are encountered during bioventing at this site, AFCEE may recommend removal of the blower system and proper abandonment of the VW and MPs.

3.0 SITE 2

3.1 Pilot Test Design and Construction

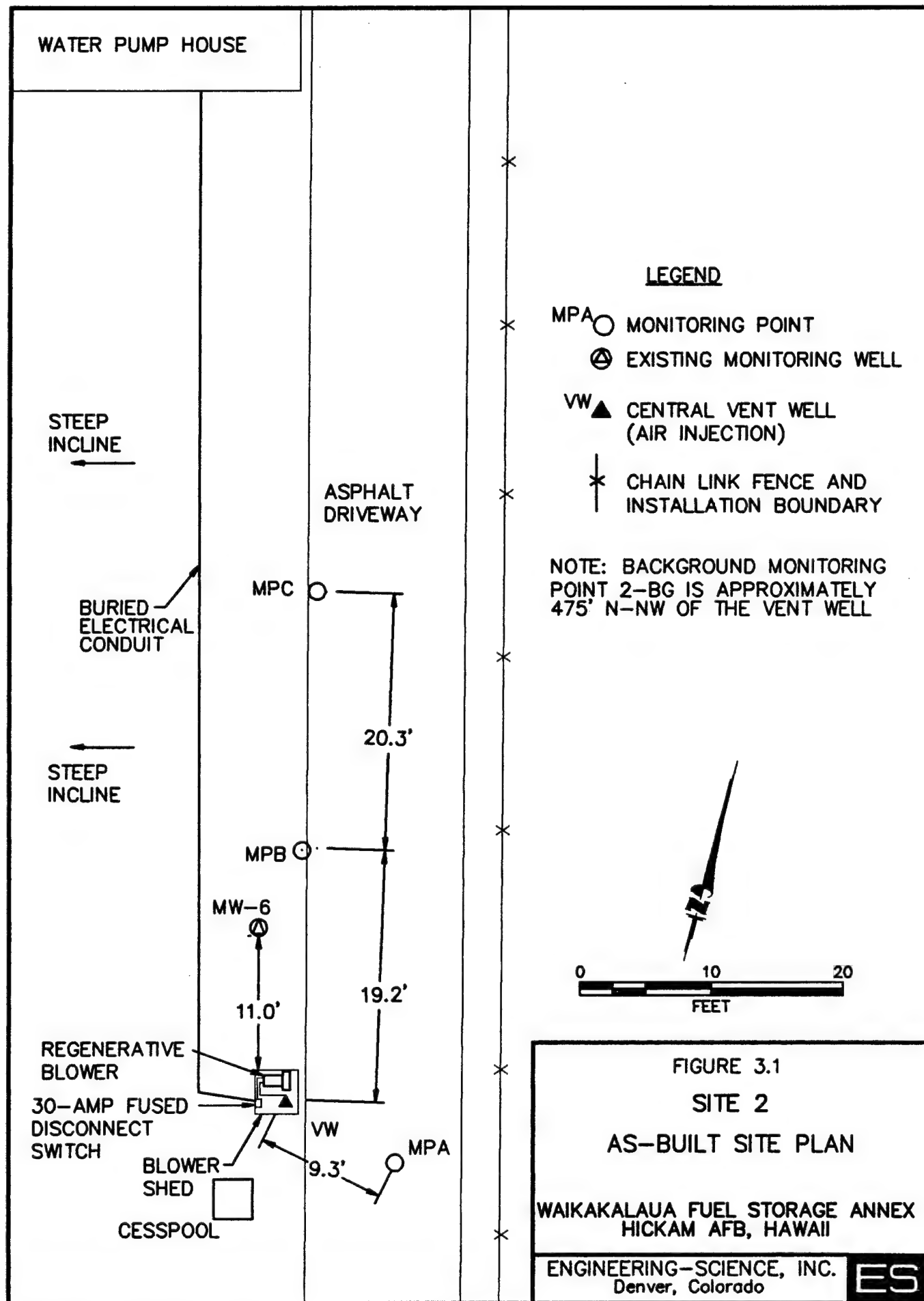
An air injection VW and four MPs, including a background MP, were installed at Site 2 on the Waikakalaua Fuel Storage Annex starting on March 26, 1993, and ending on April 20, 1993. Drilling services were provided by Geolabs-Hawaii, Inc., of Honolulu, Hawaii. Well installation and soil sampling were directed by Mr. John Ratz, the ES site manager, and Mr. Craig Miller, the ES site geologist. The following sections describe the final design and installation of the bioventing system at this site.

One VW, four MPs (MPA, MPB, MPC, and 2-BG), and a blower unit were installed at Site 2. Figures 3.1 and 3.2, respectively, depict the locations of and a hydrogeologic cross section for the VW and MPs completed at Site 2. The background MP (2-BG) was placed in uncontaminated soil approximately 475 feet north-northwest of the VW.

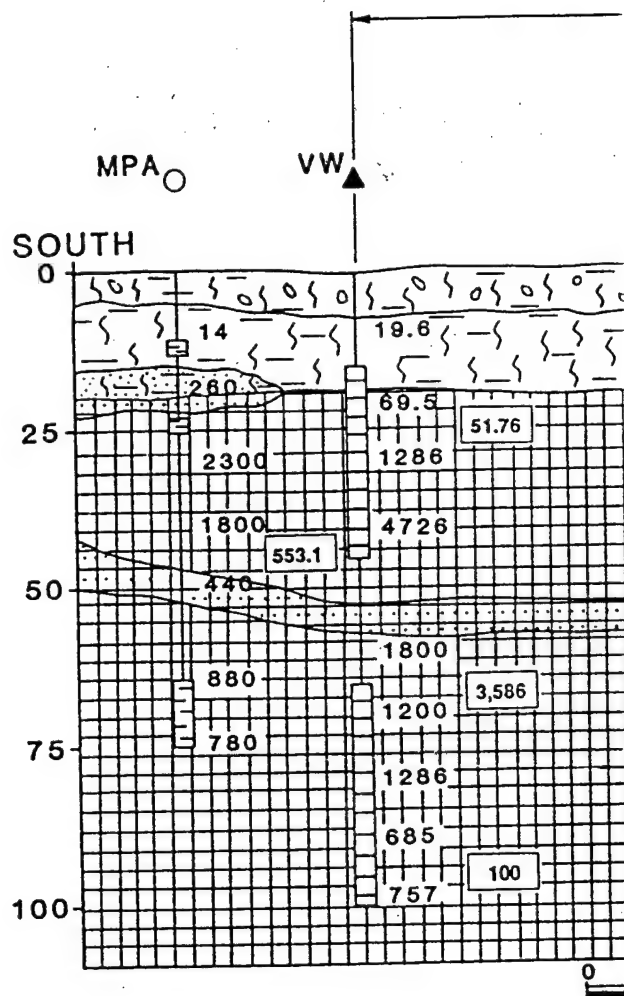
3.1.1 Air Injection Vent Well

The air injection VW was installed following procedures described in the AFCEE bioventing protocol document (Hinchee et al., 1992). The VW was installed in soil that contained hydrocarbon contamination below 21 feet bgs. A zone of perched water was encountered at depths between 52 and 57 feet bgs. Figure 3.3 shows construction details for the VW.

The VW was constructed using 4-inch-diameter, Schedule 40 PVC casing with two intervals of 0.02-inch slotted screen. The shallow screen was installed from 15.75 to 45.75 feet bgs, and the deep screen was installed from 65.75 to 100.75 feet bgs. This two-screen configuration was required to prevent the perched water from entering the well casing, and to supply oxygen to unsaturated soils above and below the perched water zone. The annular space between the well casing and the borehole was filled with number 3 silica sand, bentonite, and bentonite/cement grout. Sand was placed from the bottom of the borehole to 63 feet bgs. From 46.5 to 63 feet bgs, bentonite slurry was placed to seal off the perched water zone. A second layer of sand was placed from 13 to 46.5 feet bgs. Granular bentonite was placed from 3 to 13 feet bgs to prevent injected air from short circuiting to the atmosphere. The granular bentonite was placed in 6-inch lifts, and each lift was hydrated in place using potable water. On top of the bentonite layer, approximately 3 feet of bentonite/cement grout was placed and finished flush with the ground.



Depth Below Ground Surface (Feet)



LITHOLOGIC DESCRIPTION

SILT WITH CLAY & CORAL

SILT WITH CLAY

CLAY

SAPROLITE

ZONES OF PERCHED WATER

LEGEND

MPA ○ MONITORING POINT

VW ▲ INJECTION VENT WELL

1800 FIELD SCREENING RESULTS FOR TOTAL VOLATILE HYDROCARBONS (ppmv)

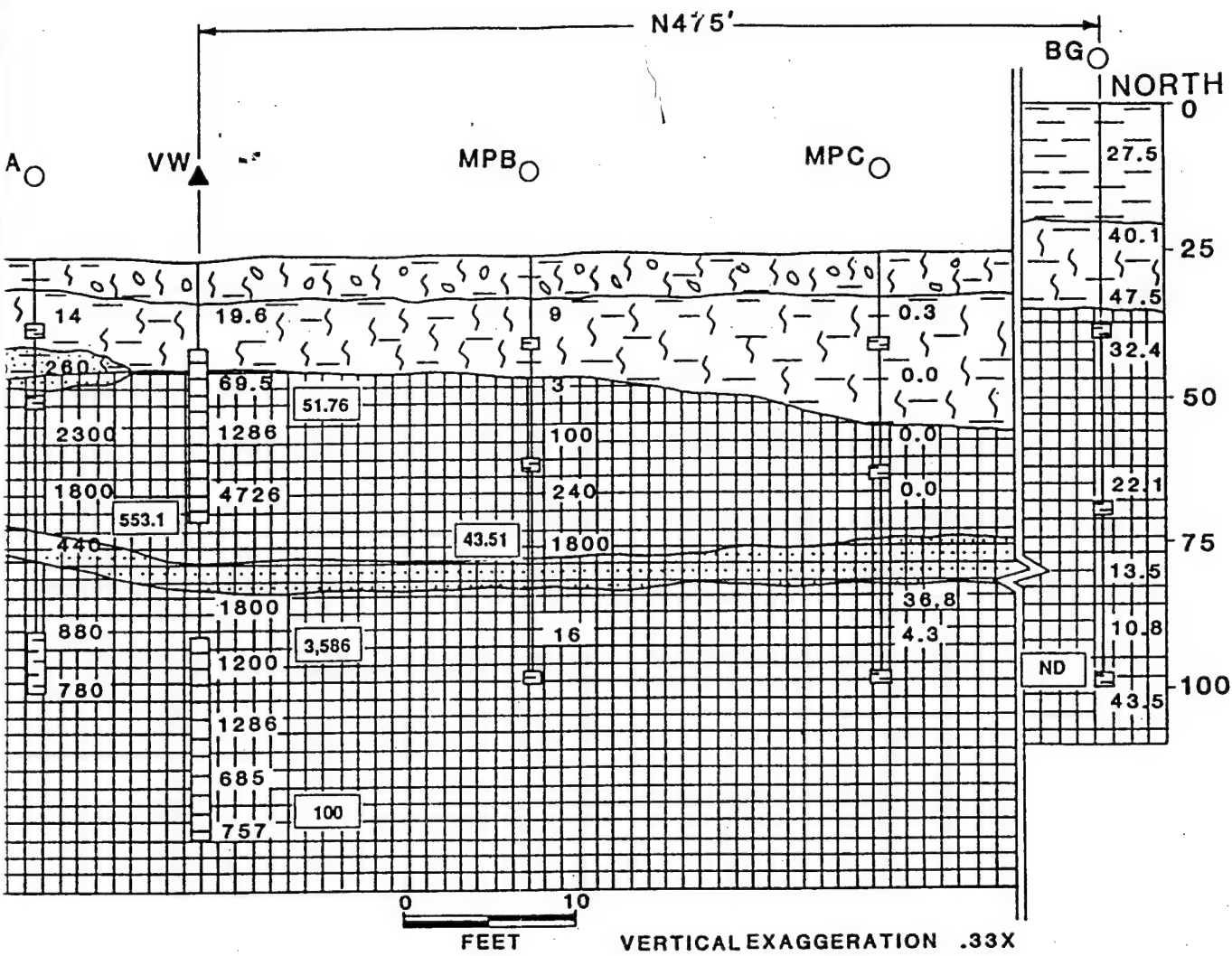
553.1 LABORATORY RESULTS FOR SOIL TOTAL PETROLEUM HYDROCARBONS (mg/kg)

ND NOT DETECTED

GEOLOGIC CONTACT, DASHED WHERE INFERRED

MONITORING POINT SCREENED INTERVAL

SCREENED WELL INTERVAL



CLAY

ZONES OF PERCHED
WATER

— GEOLOGIC CONTACT,
DASHED WHERE INFERRED

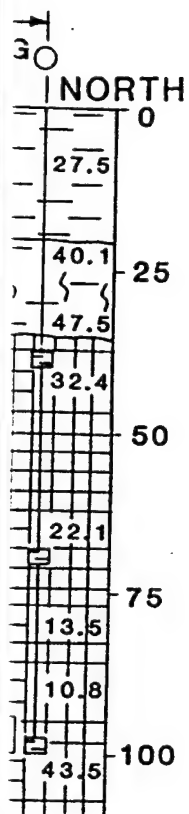
— MONITORING POINT
SCREENED INTERVAL

— SCREENED WELL INTERVAL

2

WA

EN



Depth Below Ground Surface (Feet)

FIGURE 3.2

**SITE 2
HYDROGEOLOGIC
CROSS SECTION**

WAIKAKALAUUA FUEL STORAGE ANNEX
HICKAM AFB, HAWAII

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Denver, Colorado

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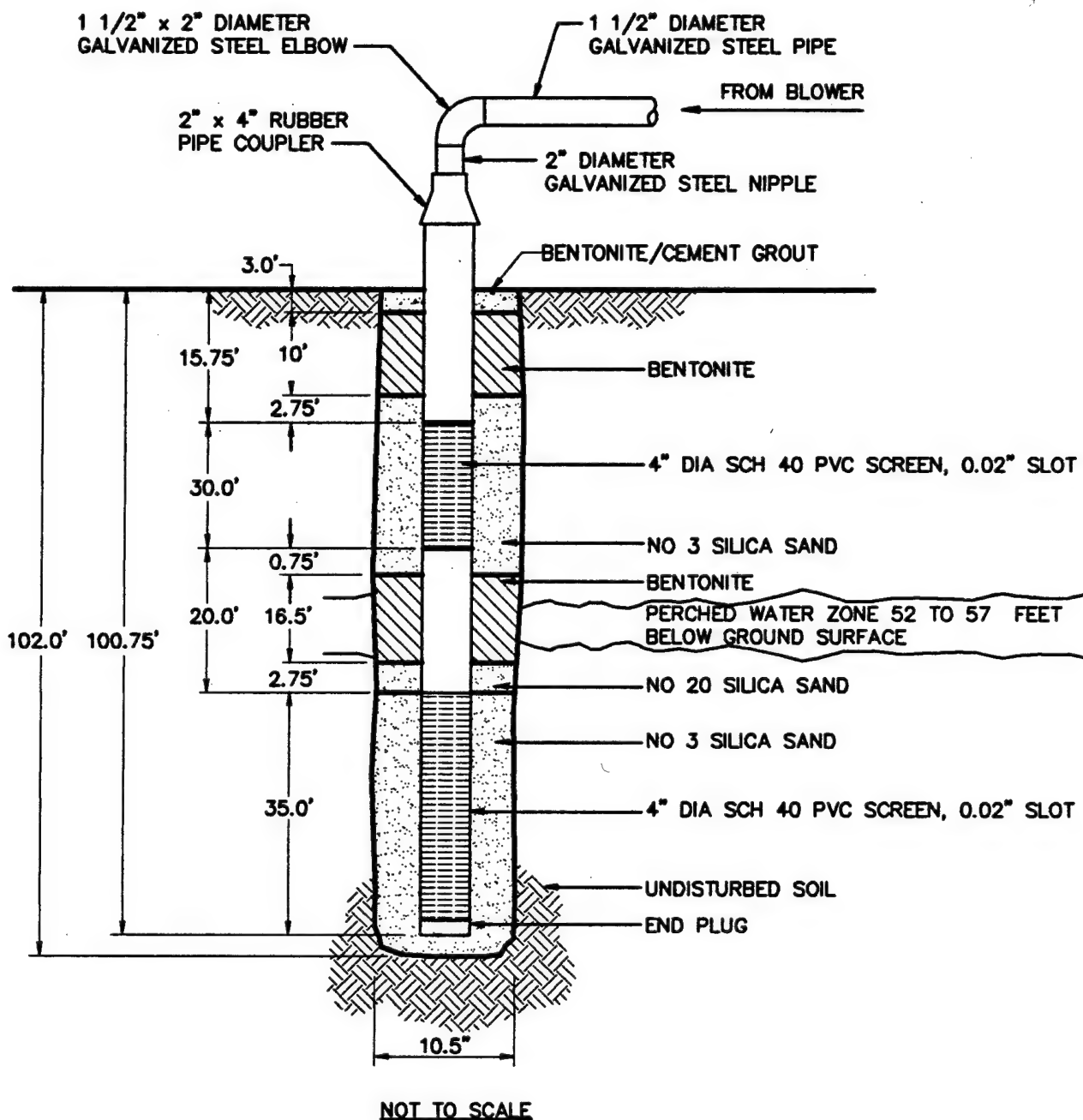


FIGURE 3.3

SITE 2
AS-BUILT INJECTION VENT WELL
CONSTRUCTION DETAIL

WAIKAKALAUJA FUEL STORAGE ANNEX
HICKAM AFB, HAWAII

ENGINEERING-SCIENCE, INC.
Denver, Colorado

ES

surface. The well casing was cut off several inches above the ground surface, and the casing was connected to a galvanized steel header using a rubber pipe coupler.

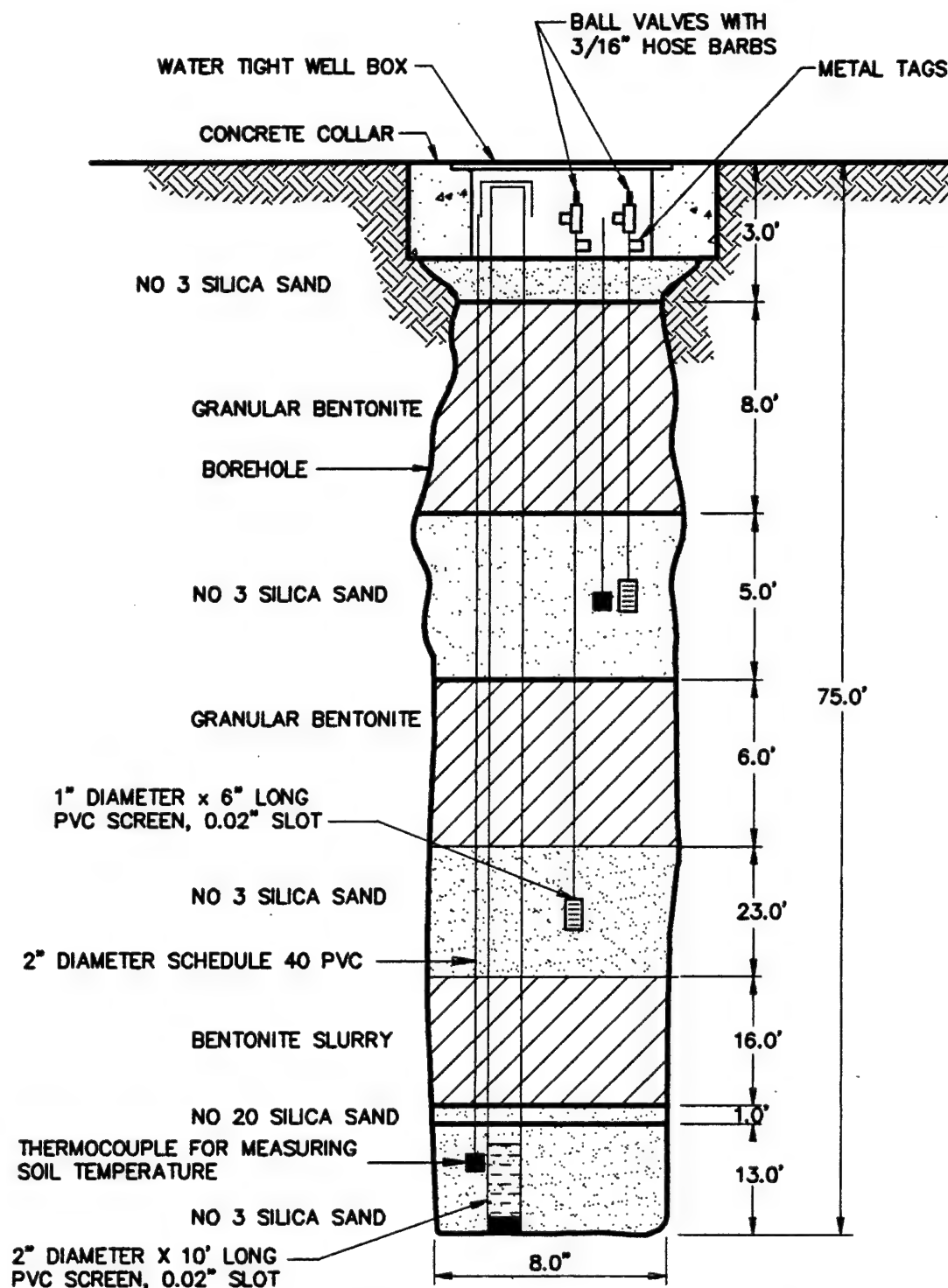
3.1.2 Monitoring Points

Four MPs (MPA, MPB, MPC, and 2-BG) were constructed at Site 2, and three screens were installed at each MP location. Existing monitoring well MW-6 was also used as an MP. A zone of perched water was encountered at MPA, MPB, and MPC at approximately 55 feet bgs. A shallow zone of perched water was also encountered at MPA from 15 to 17 feet bgs. The as-built construction detail for MPA is illustrated in Figure 3.4. At MPA, the screens were installed at 12.4-, 24.3-, and 70-foot depths (to the center of the screen). The 12.4- and 24.3-foot monitoring intervals were constructed using 6-inch sections of 1-inch diameter PVC well screen and a 0.25-inch-diameter Schedule 80 PVC riser pipe extending to the ground surface. At the top of each riser, a ball valve and a 3/16-inch hose barb were installed. The deep monitoring interval was constructed using 2-inch-diameter Schedule 40 PVC so that a bailer could be used to remove water from the point. The screen (0.02-inch slot) was installed from 65 to 75 feet bgs. The top of MPA was completed with a 12-inch flush-mounted metal well protector set in a concrete base. Thermocouples were installed at the 12.4- and 70-foot depths to measure soil temperature variations.

The as-built construction detail for MPB is shown in Figure 3.5. Construction details for MPC and 2-BG are similar to those shown for MPB, but the screened depths and sand and bentonite thickness vary from those used in MPB. At MPB, the screens were installed at 14.8-, 36.1-, and 72.8-foot depths. Screens at MPC were installed at 15-, 37.6-, and 73.2-foot depths, and the screens at 2-BG were installed at 39.6-, 70.6- and 100.6-foot depths. The ground surface elevation at 2-BG is approximately 25 feet higher than the elevation at MPA, MPB, and MPC. Therefore, the screens at 2-BG have been installed at approximately the same elevation as those at MPA, MPB, and MPC. Each MP monitoring interval in MPB, MPC, and 2-BG was constructed using a 6-inch section of 1-inch-diameter PVC well screen and a 0.25-inch-diameter Schedule 80 PVC riser pipe extending to the ground surface. At the top of each riser, a ball valve and a 3/16-inch hose barb were installed. The top of each MP was completed with an 8-inch flush-mounted metal well protector set in a concrete base.

3.1.3 Blower Unit

A 2.5-horsepower Gast® R5125Q-50 regenerative blower was used for both initial and extended pilot testing at Site 2. During the initial air permeability test, the unit was energized by 230-volt, single-phase, 30-amp power from a temporary exterior receptacle. The fixed unit is energized by 230-volt single-phase, 30-amp line power from a newly installed underground power line and aboveground breaker installed by base electricians. The configuration and instrumentation for this system are shown on Figure 3.6. The blower is currently transporting air at a flow rate of approximately 75 acfm for the extended pilot test. After blower installation and startup, ES engineers provided an O&M manual, including maintenance instructions, equipment specifications and monitoring forms, to base personnel. A copy of the O&M instructions is provided in Appendix A.



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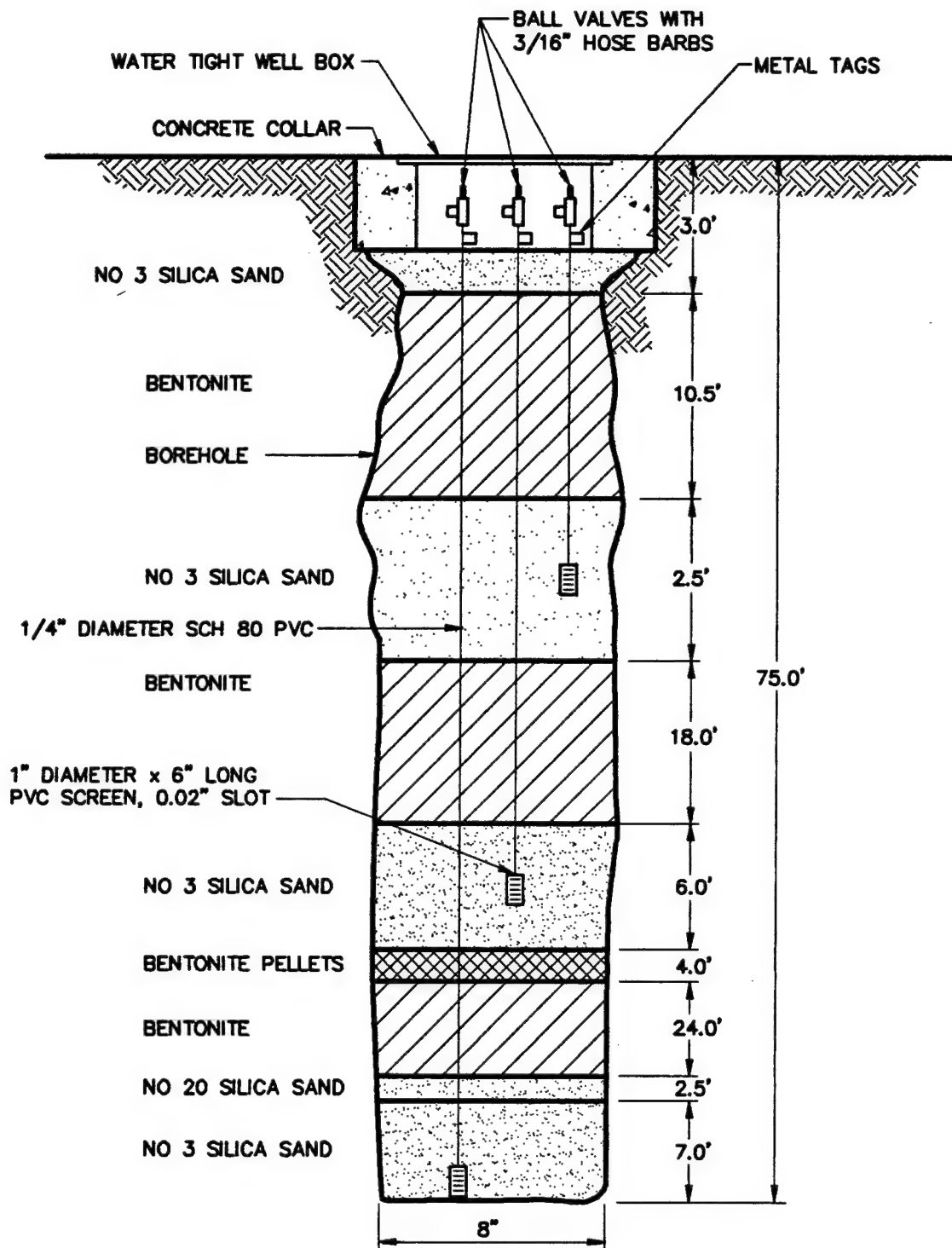
FIGURE 3.4

**SITE 2
AS-BUILT MONITORING POINT
MPA CONSTRUCTION DETAIL**

WAIKAKALAU FUEL STORAGE ANNEX
HICKAM AFB, HAWAII

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NOT TO SCALE

FIGURE 3.5

**SITE 2
AS-BUILT MONITORING POINT
MPB CONSTRUCTION DETAIL**

WAIKAKALAU FUEL STORAGE ANNEX
HICKAM AFB, HAWAII

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LEGEND

- ① INLET AIR FILTER - SOLBERG® AJ134E
- ② VACUUM GAUGE (0-60 in H₂O)
- ③ BLOWER - GAST® 2HP R5125Q-50
- ④ MANUAL PRESSURE RELIEF (BLEED) VALVE - 1 1/2" GATE
- ⑤ AUTOMATIC PRESSURE RELIEF VALVE, SET TO RELEASE AT 54 in H₂O PRESSURE
- ⑥ TEMPERATURE GAUGE (0-250 °F)
- ⑦ PRESSURE GAUGE (0-100 in H₂O)
- ⑧ STARTER - FURNAS® 14CSE32DA NEMA 3, WITH START/STOP, OVERLOAD SET AT 13AMPS
- ⑨ DISCONNECT SWITCH - 240V/SINGLE PHASE/30 AMP.

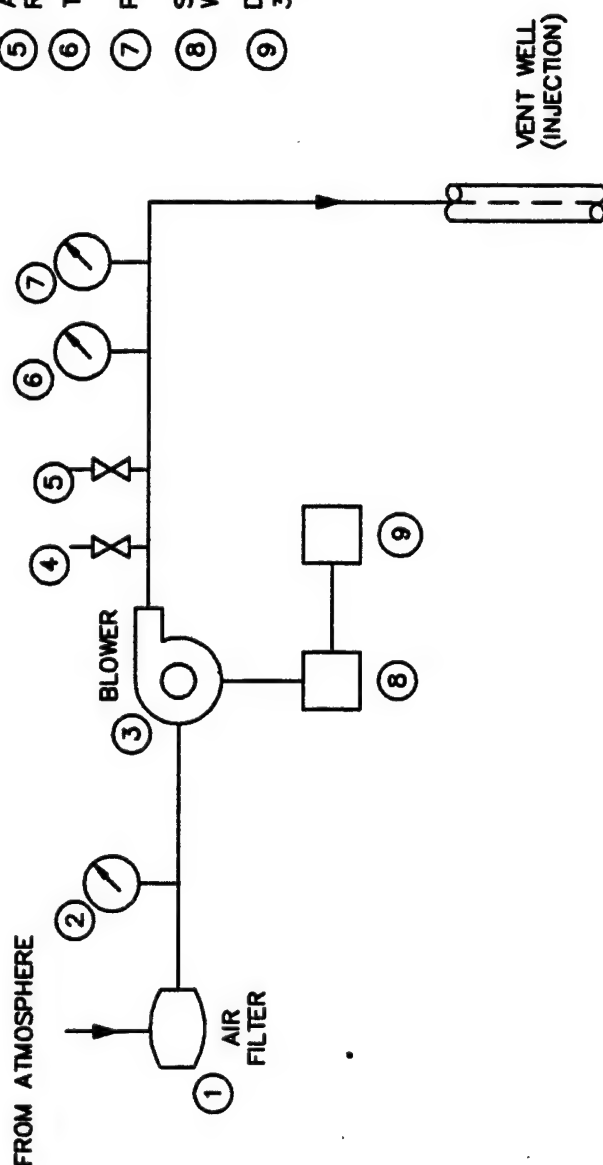


FIGURE 3.6

SITE 2 AS-BUILT BLOWER SYSTEM FOR AIR INJECTION

WAIKAKALAU FUEL STORAGE ANNEX
HICKAM AFB, HAWAII

ENGINEERING-SCIENCE, INC.
Denver, Colorado

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3.2 PILOT TEST SOIL AND SOIL GAS SAMPLING RESULTS

3.2.1 Sampling Results

Soils at Site 2 are divided into three distinct layers (Figure 3.2). From the surface to approximately 7 feet bgs, a layer of silt with clay and coral fragments was encountered. The soil from 7 to 20 feet bgs was composed of silt with clay. Below 20 feet bgs, a layer of saprolite was encountered which extends to a depth of at least 100 feet bgs. Two zones of perched water were encountered during drilling. One zone of perched water was found at approximately 55 feet bgs in the VW, MPA, MPB, and MPC. This zone was between 4 and 8 feet thick, and appeared to be under some hydraulic head. After the zone was punctured during drilling, water levels in the boreholes rose to 45 to 50 feet bgs, depending upon the drilling location. A second zone of perched water was encountered at MPA from 15 to 17 feet bgs. The groundwater table at this site is estimated at approximately 500 feet bgs, and was not encountered at any time during drilling. No free product was encountered during drilling. More detailed hydrogeologic information regarding Site 2 can be found in the hydrogeologic cross section (Figure 3.2) and the geologic boring logs (Appendix B).

Contaminated soils were identified based on visual appearance, odor, and VOC field screening results. Petroleum-contaminated soils were encountered at depths below 20 feet bgs at the VW and MPA, and at depths below 30 feet bgs at MPB. No significant petroleum contamination was discovered at MPC or the background MP (2-BG) during field screening, suggesting that the petroleum contamination may be contained within a 40 to 45 foot radius of the cesspool (Figure 3.1). Contaminated soils from the VW, MPA, and MPB had a strong hydrocarbon odor. Cuttings from the VW and MPB boreholes had a sour, vinegary scent at some depth intervals, possibly caused by the accumulation of anaerobic biodegradation byproducts. Field headspace samples were analyzed using benzene and vinyl chloride Dräger® tubes; neither compound was detected.

Soil samples for laboratory analysis were collected from 18-inch split-spoon samplers with 2-inch-diameter brass liners. Soil samples were screened for VOCs using a PID to determine the presence of contamination and to select soil samples for laboratory analysis. Soil samples for laboratory analysis were collected from the VW, MPA, MPB, and 2-BG. Three laboratory samples were collected from the VW at depths of 29.5, 60, and 90 feet bgs. At MPA and MPB, laboratory samples were collected at depths of 40 and 50 feet bgs, respectively. A soil sample for laboratory analysis was also collected from 2-BG at a depth of 100 feet bgs.

Soil gas samples were collected from the completed VW, at 24.3 feet bgs from MPA, at 37.6 feet bgs from MPC, and at 70.6 feet bgs from 2-BG. Soil gas samples were collected using new 3-liter Tedlar® bags and vacuum chambers. After the samples were collected in the Tedlar® bags, they were transferred into 1-liter SUMMA® canisters and shipped to the laboratory.

Soil samples were shipped to the Pace, Inc. laboratory in Novato, California, for chemical and physical analysis. Soil samples VW-29.5, VW-90, MPA-40, and MPB-50 were analyzed for TRPH, BTEX, iron, alkalinity, TKN, and several physical parameters. Soil sample VW-60 was analyzed for VOCs by Method SW8240,

semivolatile organics by Method SW8270, TRPH, iron, alkalinity, TKN, and several physical parameters. The volatile and semivolatile analyses were performed to determine if solvents or other non-fuel related hydrocarbon contaminants were present in contaminated soils at Site 2. Soil sample BG-100 was analyzed only for TRPH and BTEX. Soil gas samples were shipped to Air Toxics, Inc. in Rancho Cordova, California, for TVH and BTEX analysis. TVH analyses were referenced to JP-4 jet fuel. The results of these analyses are provided in Table 3.1. Chain-of-custody forms are provided in Appendix B.

TRPH concentrations ranged from 43.51 to 3,586 mg/kg in contaminated soils. Total BTEX concentrations ranged from 10.25 to 120.42 mg/kg in contaminated soils. Phenol, 2-methylphenol, and 4-methylphenol were detected in soil sample VW-60. These compounds are probably intermediate products in the mineralization of BTEX compounds; their presence suggests that some fuel biodegradation was occurring naturally at Site 2 before the installation of the bioventing system. Iron concentrations in the soils at Site 2 are very high in comparison to those encountered at other AFCEE bioventing sites. Soil pH values were slightly acidic, ranging from 4.0 to 5.9. This could be caused by the accumulation of acidic byproducts of naturally occurring anaerobic fuel degradation.

3.2.2 Exceptions To Test Protocol Procedures

Procedures described in the protocol document (Hinchee et al., 1992) were used to complete treatability tests at Site 2, with the following exceptions. Due to the unique nature and the depth of the soils at Site 2, the actual scope of soil and soil gas sampling and analysis exceeded the scope of sampling set forth in the protocol document. Three laboratory samples were collected from the VW borehole (Table 3.1); the protocol document specifies that only one laboratory sample be collected from this drilling location. To determine if solvents or other non-petroleum hydrocarbon contaminants were present at Site 2, soil sample VW-60 was analyzed by Methods SW8240 and SW8270 in addition to the analyses required by the established protocol. A soil sample BG-100 was collected from background point 2-BG and a soil gas sample was collected from screened interval 2-BG-70.6; these samples also are not specified in the protocol document.

Because perched water was encountered at the site, VW and MP construction details varied slightly from those specified in the protocol. A two-screen configuration was used for the VW (see Section 3.1.1), and a 2-inch diameter Schedule 40 PVC MP screen was installed at MPA (see Section 3.1.2).

Pressure response could not be measured during the initial stage of the air permeability test, as called for in the protocol document. Therefore, to demonstrate pressure influence, pressure decreases were measured at the MPs when air injection was stopped at the end of the air permeability test. This activity is explained more fully in Section 3.3.2.

TABLE 3.1

SITE 2
SOIL AND SOIL GAS ANALYTICAL RESULTS
WAIKAKALAU FUEL STORAGE ANNEX
HICKAM AFB, HAWAII

Analyte (Units) ^{a/}	Sample Location-Depth (feet below ground surface)					
	<u>VW-29.5</u>	<u>VW-60^{b/}</u>	<u>VW-90</u>	<u>MPA-40</u>	<u>MPB-50</u>	<u>BG-100</u>
<u>Soil Hydrocarbons</u>						
TRPH (mg/kg)	51.76	3,586	100	553.1	43.51	ND ^{c/}
Benzene (mg/kg)	ND	1.7	1.6	ND	0.42	ND
Toluene (mg/kg)	5.1	3.6	17	4.5	29	ND
Ethylbenzene (mg/kg)	8.1	0.85	7.8	6.5	14	ND
Xylenes (mg/kg)	40	4.1	44	31	77	ND
Phenol (mg/kg)	NS ^{d/}	1.1	NS	NS	NS	NS
2-Methylphenol (mg/kg)	NS	0.4	NS	NS	NS	NS
4-Methylphenol (mg/kg)	NS	0.79	NS	NS	NS	NS
<u>Soil Gas Hydrocarbons</u>						
	<u>VW</u>	<u>MPA-24.3</u>	<u>MPC-37.6</u>	<u>BG-70.6^{e/}</u>		
TVH (ppmv)	19,000	22,000	250	77.5		
Benzene (ppmv)	46	ND	0.083	ND		
Toluene (ppmv)	86	ND	0.45	0.030		
Ethylbenzene (ppmv)	16	21	0.18	0.014		
Xylenes (ppmv)	52	66	0.58	0.041		

TABLE 3.1 (Continued)

SITE 2
SOIL AND SOIL GAS ANALYTICAL RESULTS
WAIKAKALAU FUEL STORAGE ANNEX
HICKAM AFB, HAWAII

Analyte (Units) ^{a/}	Sample Location-Depth (feet below ground surface)				
	<u>VW-29.5</u>	<u>VW-60</u>	<u>VW-90</u>	<u>MPA-40</u>	<u>MPB-50</u>
<u>Soil Inorganics</u>					
Iron (mg/kg)	106,000	119,000	85,900	90,400	93,800
Alkalinity (mg/kg as CaCO ₃)	ND	ND	74	ND	ND
pH (units)	4.9	4.0	4.3	5.9	4.3
TKN (mg/kg)	ND	ND	ND	110	50
Phosphates (mg/kg)	760	590	450	480	78
<u>Soil Physical Parameters</u>	<u>VW-29.5</u>	<u>VW-60</u>	<u>VW-90</u>	<u>MPA-40</u>	<u>MPB-50</u>
Moisture (% wt.)	32.6	33.4	29.3	34.8	38.5
Gravel (%)	0	0	0	0	0
Sand (%)	22	25.8	52.1	54.0	6.9
Silt (%)	56	59.2	39.4	31.7	47.6
Clay (%)	22	15.0	8.5	14.3	45.5
<u>Soil Temperature (°F)</u>	<u>MPA-12.4</u>	<u>MPA-70</u>			
	72.4	79.2			

- a/ TRPH = total recoverable petroleum hydrocarbons; mg/kg = milligrams per kilogram; TVH = total volatile hydrocarbons; ppmv = parts per million, volume per volume; CaCO₃ = calcium carbonate; TKN = total Kjeldahl nitrogen, °F = degrees Fahrenheit.
- b/ All parameters except TRPH were analyzed by SW8240 and SW8270.
- c/ ND = not detected.
- d/ NS = not sampled.
- e/ Results averaged with duplicate sample.

3.3 PILOT TEST RESULTS

3.3.1 Initial Soil Gas Chemistry

Prior to initiating any air injection, all MPs, the VW, and existing monitoring well MW-6 were purged, and initial oxygen, carbon dioxide, and TVH concentrations were determined using portable gas analyzers, as described in the technical protocol document (Hinchee et al., 1992). Table 3.2 summarizes the initial soil gas chemistry at Site 2. The results strongly indicate that biological fuel degradation is occurring in vadose zone soils at Site 2.

Oxygen concentrations were below 5 percent in samples collected from points installed in contaminated soil (VW, MPA-24.3, MPB-36.1, and MW-6). Oxygen concentrations of 6.9 and 11.5 percent were observed at MPC-37.6 and 2-BG-70.6, respectively. Although these oxygen concentrations are higher than those found in fuel-contaminated soils, they are still low relative to typical background readings, indicating that some aerobic degradation of naturally occurring organic material may be occurring. Also, because the soils at Site 2 have an elevated iron content, some oxygen in the soil gas could be lost via iron oxidation. Carbon dioxide was present at elevated concentrations in fuel-contaminated soils, ranging from 6.1 to 11.3 percent in soil gas samples containing over 20,000 ppmv of TVH as measured with field instruments. The carbon dioxide concentration at the background point was 0.3 percent. Because fuel-contaminated soil gas at Site 2 contains low oxygen and high carbon dioxide concentrations relative to uncontaminated background soil gas, oxygen consumption and carbon dioxide accumulation in contaminated soil gas can be attributed mainly to petroleum hydrocarbon degradation.

3.3.2 Air Permeability

An air permeability test was attempted at Site 2 according to protocol document procedures. Air was injected into the VW for approximately 6 days at an average injection pressure of 55 inches of water. The flow rate into the VW increased from approximately 20 acfm to 75 acfm over the 6-day air injection period. There was no noticeable pressure influence at any of the MPs during the first 2 days of testing due to the impermeable nature of the soil and the high moisture content. By the end of the air injection period, pressure response was measurable at two MP screens; MPA-24.3 and MPB-36.1. To demonstrate that this pressure response was caused by air injection rather than atmospheric phenomena, air injection was discontinued and the decline in pressure at the two MP screens was observed over time (Table 3.3). At both points, the pressure dropped rapidly to zero after the bioventing system had been turned off, confirming that these MP screens were in the zone of pressure influence of the pilot test system.

Because pressure response data could not be obtained during the first 2 days of the air permeability test, the steady-state method of determining soil gas permeability was selected. Using the steady-state method, a soil gas permeability

TABLE 3.2
SITE 2
INITIAL SOIL GAS CHEMISTRY
WAIKAKALAU FUEL STORAGE ANNEX
HICKAM AFB, HAWAII

MP	Depth (ft)	O ₂ (%)	CO ₂ (%)	Field TVH (ppmv)	Lab TVH (ppmv)
VW	15.75-45.75 and 65.75-100.75 ^{a/}	4.9	11.3	>20,000	19,000
A	24.3	0.0	6.1	>20,000	22,000
B	36.1	3.7	0.4	6,500	NA ^{b/}
C	37.6	6.9	3.8	180	250
MW-6	≈150	2.9	10.8	>20,000	NA
2-BG ^{c/}	70.6	11.5	0.3	150	78

- a/ VW is screened in two sections (Figure 3.3); a single initial sample is reported as these are not discrete sampling intervals.
b/ NA = not analyzed.
c/ Background well at Waikakalaua Fuel Storage Annex.

TABLE 3.3

SITE 2

**PRESSURE RESPONSE AT THE END OF THE 6-DAY AIR PERMEABILITY TEST
WAIKAKALAUUA FUEL STORAGE ANNEX
HICKAM AFB, HAWAII**

Monitoring Location Depth (ft bgs)	Pressure Response In MP (inches of water)	
	<u>MPA</u> 24.3	<u>MPB</u> 36.1
Elapsed Time (min.)		
0	2.05	0.27
0.25	1.6	0.24
0.75	1.2	0.21
1	0.9	0.18
1.25	0.6	0.14
1.75	0.45	0.10
2	0.30	0.08
3	0.19	0.07
4	0.0	0.05
5	0.0	0.05
6	0.0	0.03
8	0.0	0.03

value of 4.15 darcys was calculated for intermediate-depth (20-40 feet) soils at Site 2. A radius of pressure influence of at least 20 feet was observed at these depths.

3.3.3 Oxygen Influence

The depth and radius of oxygen influence in the subsurface resulting from air injection into the central VW during pilot testing is the primary design parameter for full-scale bioventing systems. Optimization of full-scale and multiple VW systems requires pilot testing to determine the volume of soil that can be oxygenated at a given flow rate and VW screen configuration.

Table 3.4 describes the change in soil gas oxygen levels that occurred during the 6-day air injection test at the site. This air injection period produced changes in soil gas oxygen levels at a distance of at least 39.5 feet from the central VW at the intermediate depth interval. Oxygen level increases were measured at points near the VW (MPA and MPB), while decreases were measured further from the VW (MPC). The decreased oxygen level observed at MPC was the result of oxygen-deficient air from the more highly contaminated central portion of the site being forced outward by the injected air. The decrease in oxygen levels indicates significant air movement through the soils, and it is likely that oxygenated air will reach MPC with continuous injection.

MW-6 was not influenced by air injection, indicating that the deep saprolite probably cannot be oxygenated using the current VW configuration. Oxygen influence at the shallow and deep screens at each MP could not be monitored; it was not possible to collect soil gas samples from these points due to the tight nature of the soils. It is possible that these zones were temporarily saturated during MP construction, and that these points may dry out and be used during future testing. Monitoring during the extended pilot test at this site will better define the effective treatment radius.

3.3.4 In Situ Respiration Rates

In situ respiration testing was performed at Site 2 by injecting air (oxygen) and approximately 3.5 percent helium (inert tracer gas) into the VW, MW-6, MPA-24.3, and MPB-36.1 for 20 hours at a rate of approximately 1 acfm per injection point to deliver oxygen to contaminated soils. Air alone was injected into background monitoring point 2-BG-70.6 during this period. At the end of the 20-hour period, air injection ceased and changes in soil gas composition were monitored. Oxygen, TVH, carbon dioxide, and helium concentrations were measured in soil gas samples collected over a period of 100 hours following the air injection period. The observed rates of oxygen utilization were then used to estimate the aerobic fuel degradation rates at Site 2. Figures 3.7 through 3.10 present the results of *in situ* respiration testing at the site, and Table 3.5 provides a summary of the observed oxygen utilization rates. Figure 3.11 presents oxygen utilization data from 2-BG-70.6, the background MP.

Because helium is a conservative, inert gas, the change in helium concentrations over time can be useful in determining if oxygen diffusion is responsible for a portion of the oxygen lost from each MP, or if leakage is occurring due to improper MP construction. Figures 3.7 through 3.10 compare oxygen utilization and helium

TABLE 3.4
SITE 2
INFLUENCE OF AIR INJECTION AT VENT WELL
ON MONITORING POINT OXYGEN LEVELS
WAIKAKALAU FUEL STORAGE ANNEX
HICKAM AFB, HAWAII

MP	Distance From VW (ft)	Depth(ft)	Initial O ₂ (%) ^{a/}	Final O ₂ (%) ^{b/}
A	9.3	24.3	0.0	17.3
B	19.2	36.1	3.7	14.7
MW-6	11.0	≈150	0.0	0.0
C	39.5	37.6	6.4	3.3

a/ Initial O₂ samples collected prior to air permeability test and the respiration test.

b/ Duration of air injection = 142 hours.

Figure 3.7
Respiration Test
Oxygen and Helium Concentrations
Site 2 - VW
Waikakalaua Fuel Storage Annex
Hickam AFB, HI

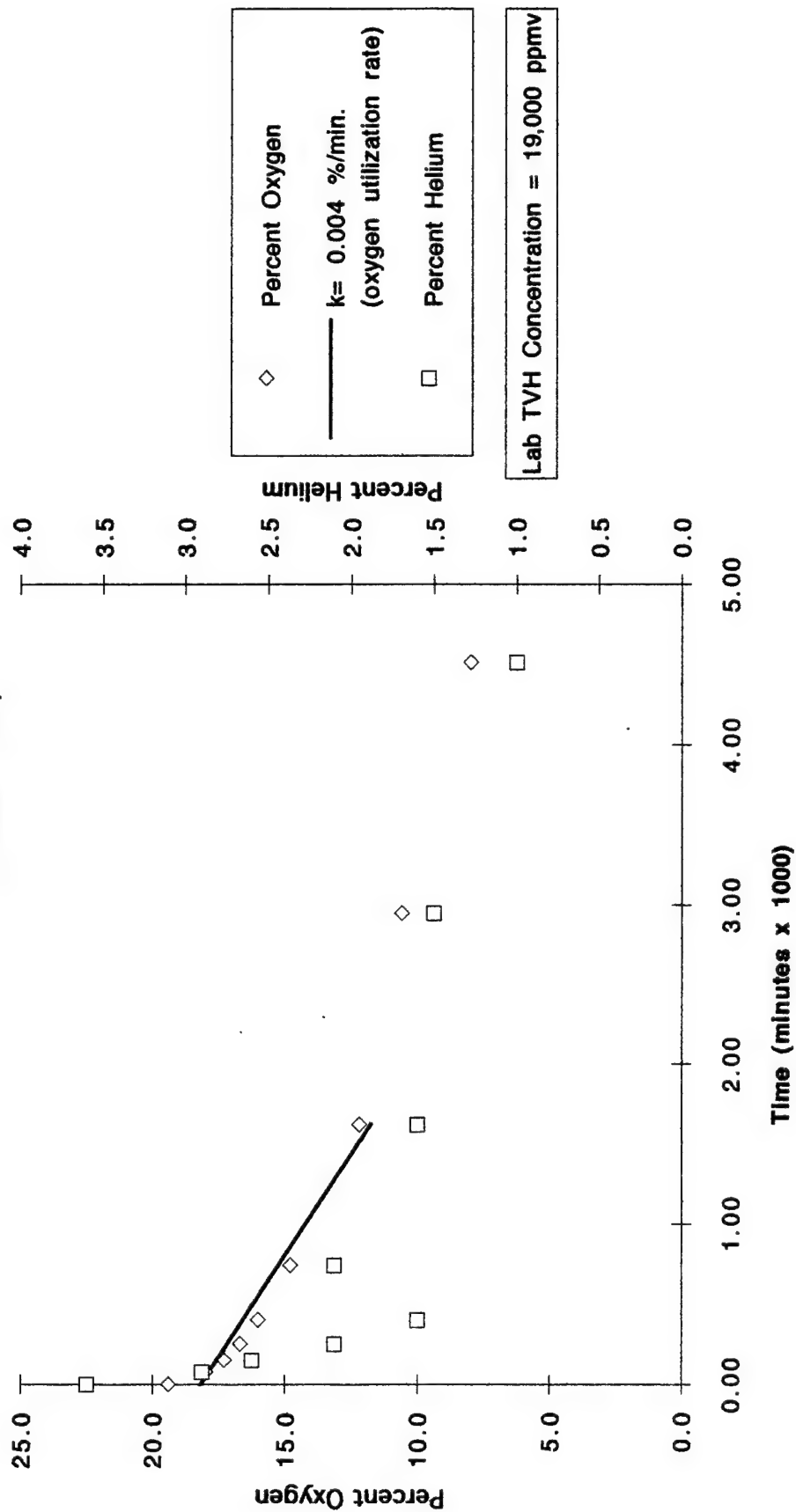


Figure 3.8
Respiration Test
Oxygen and Helium Concentrations
Site 2, MPA-24.3
Waikakalaua Fuel Storage Annex
Hickam AFB, HI

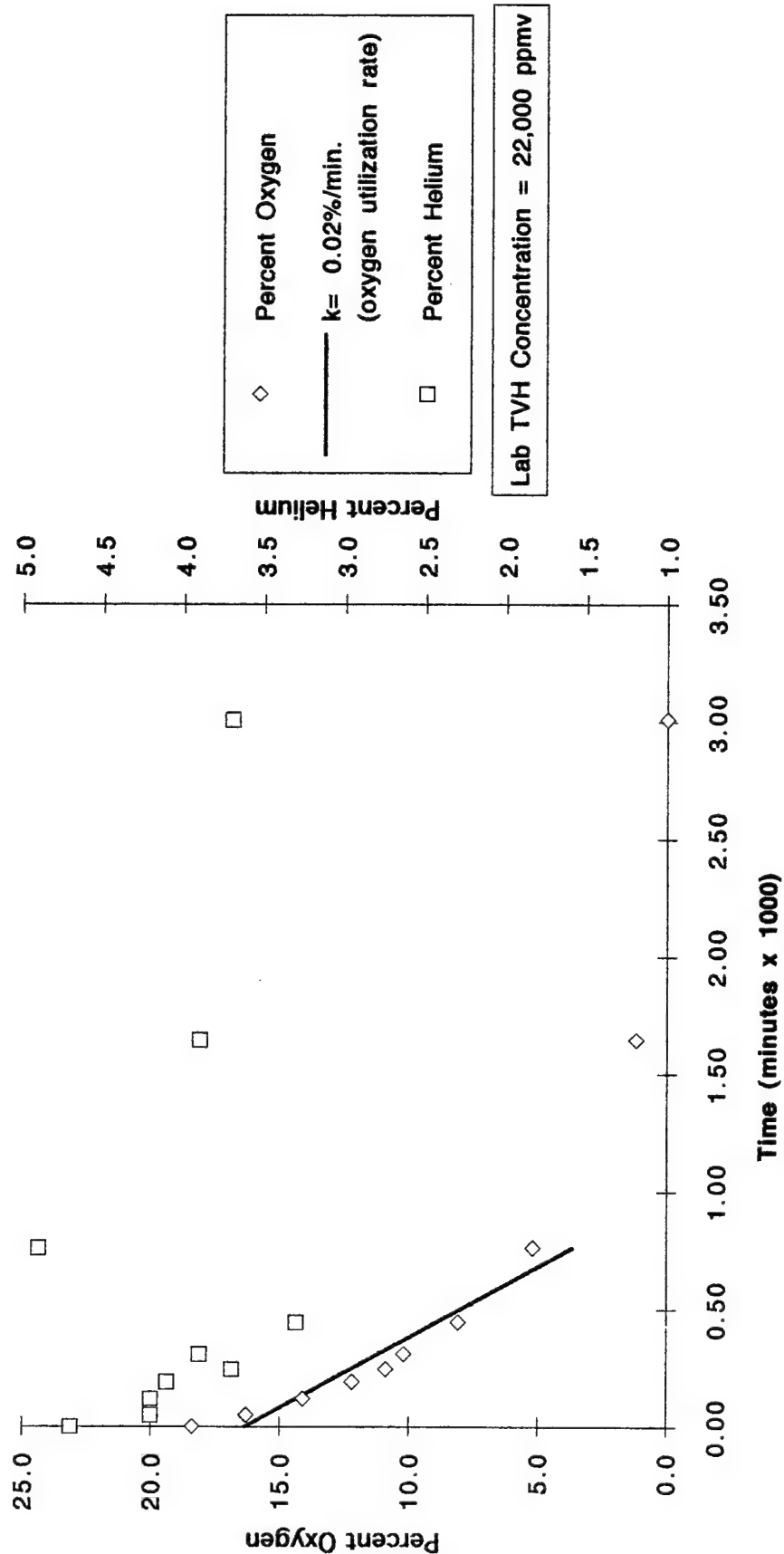


Figure 3.9
Respiration Test
Oxygen and Helium Concentrations
Site 2, MPB-36.1
Waikakalaua Fuel Storage Annex
Hickam AFB, HI

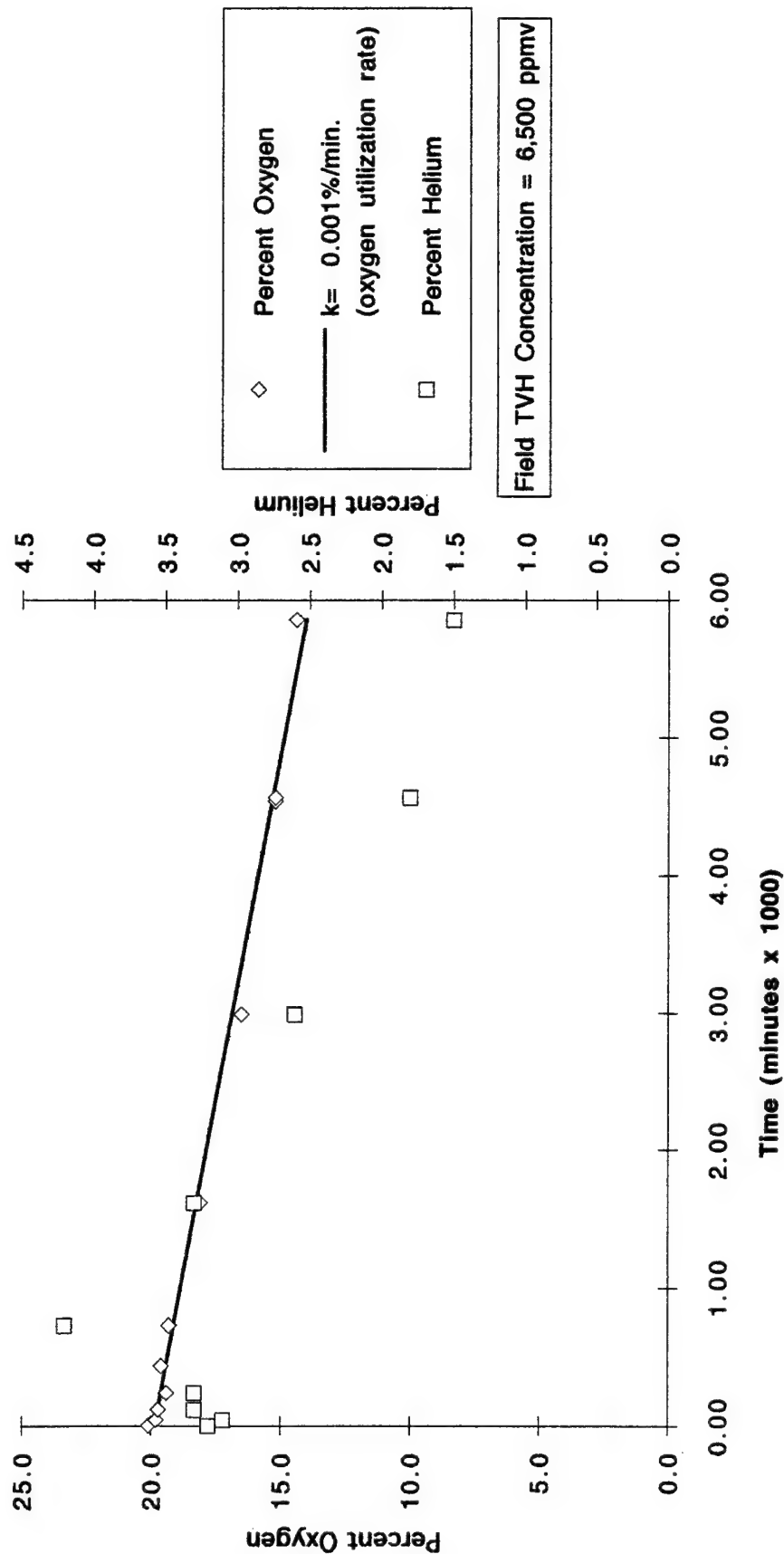


Figure 3.10
 Respiration Test
 Oxygen and Helium Concentrations
 Site 2, MW-6
 Waikakalaua Fuel Storage Annex
 Hickam AFB, HI

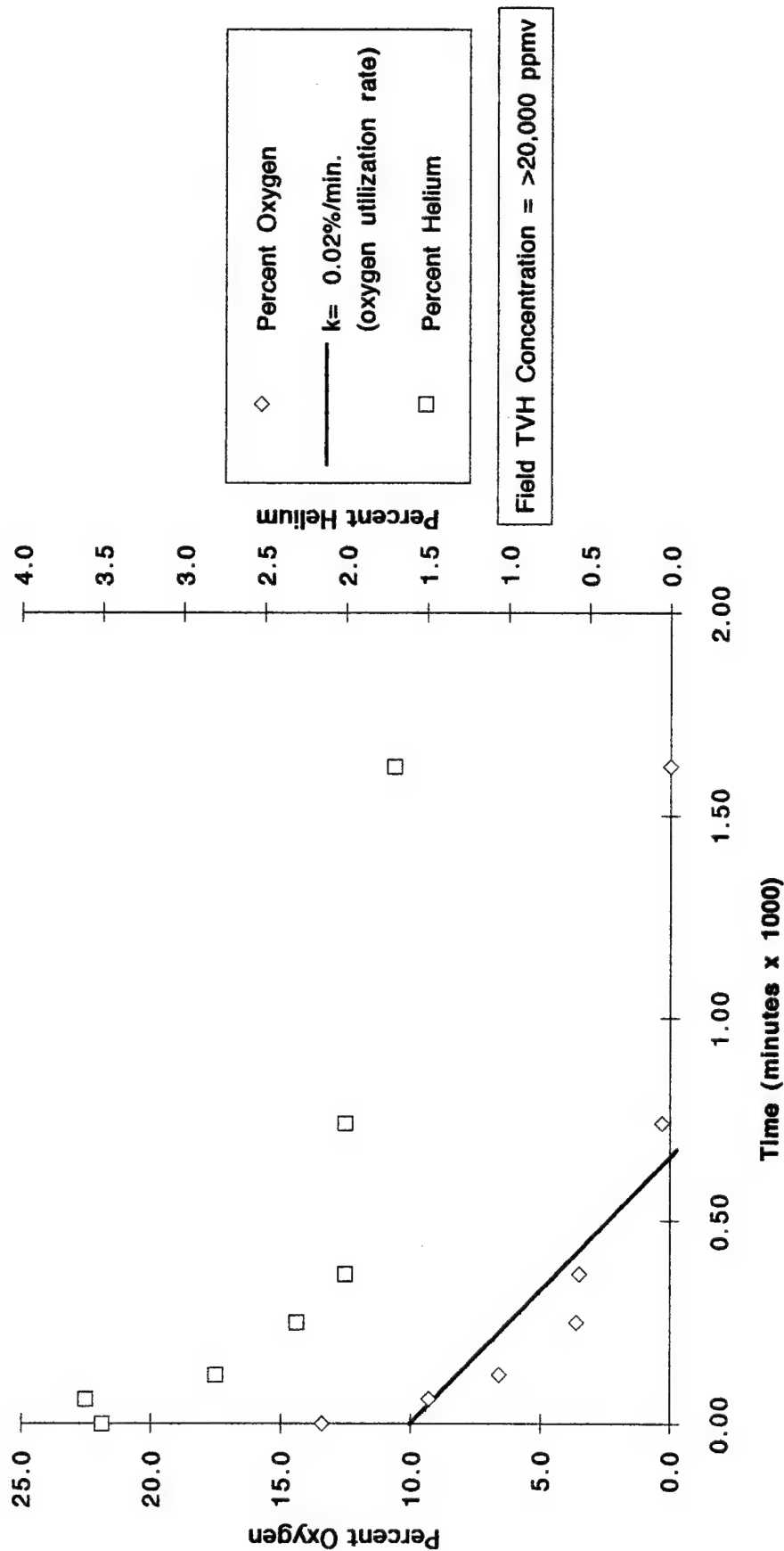
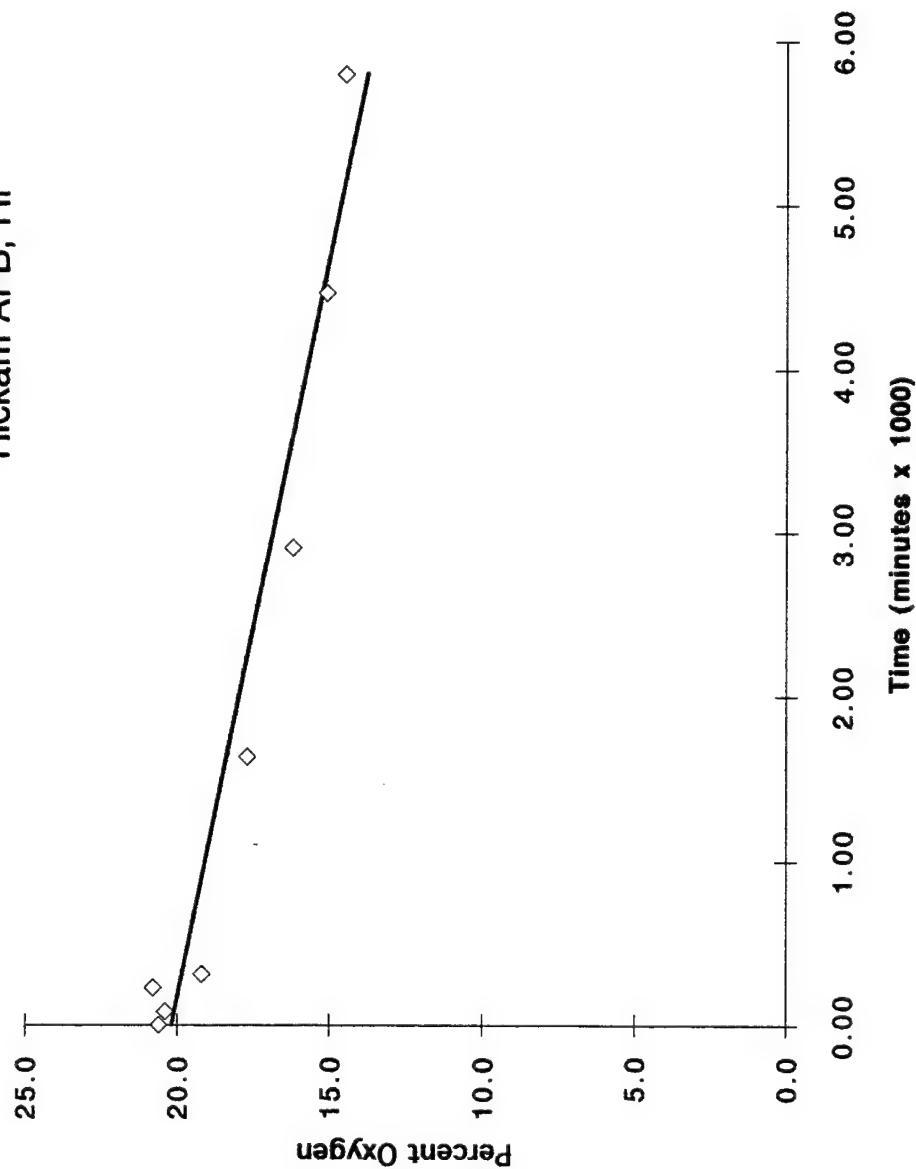


TABLE 3.5
SITE 2
OXYGEN UTILIZATION RATES
WAIKAKALAU FUEL STORAGE ANNEX
HICKAM AFB, HAWAII

MP	O ₂ Loss (%)	Test Duration (min)	O ₂ Utilization ^{a/} Rate (%/min)
VW	7.2	1,630	0.004
MPA-24.3	13.2	760	0.017
MPB-36.1	5.7	5,860	0.001
MW-6	13.1	735	0.018
2-BG-70.6	6.1	5,800	0.001

^{a/} Values based on linear regression (Figures 3.7 through 3.10).

Figure 3.11
 Respiration Test
 Oxygen Concentrations
 Site 2, 2-BG-70.6
 Waikakalaua Fuel Storage Annex
 Hickam AFB, HI



◇ Percent Oxygen

— $k = 0.001\%/min.$
 (oxygen utilization rate)

Lab TVH Concentration = 78 ppmv

retention at the MPs. At MPA-24.3 and MW-6, helium concentrations remained relatively constant, while oxygen concentrations dropped quickly to zero (Figures 3.8 and 3.10). At the VW, helium and oxygen concentrations dropped at the same rate (Figure 3.7), while helium was lost more quickly than oxygen at MPB-36.1 (Figure 3.9). Because helium will diffuse approximately three times faster than oxygen, the measured oxygen loss at the VW, MW-6, and MPA-24.3 can be attributed to bacterial respiration rather than diffusion or faulty MP construction. At MPB-36.1, oxygen loss can be partially attributed to diffusion.

Oxygen concentrations were monitored over time at 2-BG-70.6 to quantify oxygen uptake rates in uncontaminated soil (Figure 3.11). A background oxygen loss rate of 0.001 %/min was observed. A comparison of this rate with oxygen utilization rates at highly contaminated points VW, MPA-24.3, and MW-6 (0.004, 0.02, and 0.02 %/min, respectively) demonstrates that oxygen at the contaminated points is being utilized by soil bacteria primarily for the biodegradation of petroleum hydrocarbons. The oxygen uptake rate at MPB-36.1 (0.001 %/min) was the same as that observed in 2-BG-70.6. Therefore, much of the oxygen consumption at this point could be attributed to diffusion or abiotic oxygen demands rather than fuel biodegradation.

At Site 2, an estimated 800 mg of fuel per kg of soil can be degraded each year. This value is based on the average of the fuel consumption rates calculated for the VW, MW-6, and MPA-24.3. The point-specific fuel consumption rates were calculated using observed oxygen utilization rates, estimated air filled porosities, and a conservative ratio of 3.5 mg of oxygen consumed for every 1 mg of fuel biodegraded. The air-filled porosity, calculated for each sampling point, ranged from 0.022 to 0.044 liter of air per kilogram of soil. These air-filled porosities are conservatively low because they do not account for soil gas-filled vesicles observed in the saprolite. Actual fuel degradation rates in the saprolite may be higher than the estimated biodegradation rate of 800 mg/kg per year.

3.3.5 Potential Air Emissions

Ambient air quality monitoring was conducted during the air permeability test to determine if air injection would displace VOCs into the atmosphere. Air quality monitoring was conducted using a hydrocarbon analyzer during the initial 8 hours of air injection at a flow rate of 20 acfm. Monitoring took place at eight locations at Site 2 in an attempt to identify potential locations of VOC emissions from the soil. During this ambient air sampling program at Site 2, no detections of VOCs occurred over the 1 ppmv detection limit of the instrument. Thus, the bioventing system is operating at a flow rate low enough to avoid driving petroleum vapors into the atmosphere. Benzene was detected in soil gas at Site 2 at concentrations ranging from 0.083 to 46 ppmv, while toluene detections ranged from 0.03 to 86 ppmv (Table 3.1). Because the contamination is relatively deep and there is no apparent pathway for short-circuiting, the long-term potential for emission of these compounds into ambient air is minimal.

3.4 RECOMMENDATIONS

Initial bioventing tests at this site indicate that oxygen has been depleted in the contaminated soils, and that air injection is an effective method of stimulating aerobic fuel biodegradation. AFCEE has recommended that air injection continue at this site to determine the long-term radius of oxygen influence and the effect of time, available nutrients, and changing temperatures on fuel biodegradation rates.

A 2.5-horsepower regenerative blower has been installed at the site for continuous air injection. In November 1993, ES will return to the site to sample and analyze the soil gas and conduct a repeat respiration test. In April 1994, a final respiration test will be conducted, and soil and soil gas samples will be collected from the site to determine the degree of remediation achieved during the first year of *in situ* treatment.

Based on the results of the first year of pilot-scale bioventing, AFCEE will recommend one of three options:

1. Upgrade, if necessary, and continue operation of the bioventing system for full-scale remediation of the site. AFCEE can assist the base in obtaining regulatory approval for upgrading and continued operation.
2. If final soil sampling indicates significant contaminant removal has occurred, AFCEE may recommend additional sampling to confirm that cleanup criteria have been achieved.
3. If significant difficulties or poor results are encountered during bioventing at this site, AFCEE may recommend removal of the blower system and proper abandonment of the VW and MPs.

4.0 REFERENCE

Hinchee, R.E., S.K. Ong, R.N. Miller, D.C. Downey, and R. Frandt. 1992. *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing*. Prepared for USAF Center for Environmental Excellence. May.

APPENDIX A

O&M INSTRUCTIONS

APPENDIX A

OPERATION AND MAINTENANCE INSTRUCTIONS

This appendix is intended to supplement the Interim Results Report, not to replace the operations and maintenance (O&M) manuals provided to Hickam Air Force Base (AFB). Please refer to the O&M manuals for more detail.

1.0 BLOWER/MOTOR MAINTENANCE

Gast® rotary-vane blowers (Model 2567-P102) have been installed at Areas H and K, and a Gast® regenerative blower (Model R5125Q-50) has been installed at Site 2. The blower performance curves have been included in this appendix. The blower and motor are relatively maintenance free. There is no lubrication required because the blower and motor have sealed bearings. If a blower system is in need of repair, please contact John Ratz of Engineering-Science, Inc. (ES) in Denver, Colorado at (303) 831-8100.

2.0 FILTER MAINTENANCE

To avoid damage caused by passing solids through the blower, an air filter has been installed inline before the blower. By design, Gast® blowers are able to ingest small quantities of particles without damage. However, continuous ingestion of solids will damage or imbalance the impellers. The inline air filter will prevent solids from entering the blower and is rated at 99 percent efficiency to 10 microns.

The regenerative blower filter element is a polyester cloth and is cleanable and replaceable. The rotary-vane blower paper filter is replaceable. The filters should be checked weekly for the first 2 months of operation. The air filter should be cleaned or replaced when the pressure difference across the filter reaches 15 to 20 inches of water. It will be the responsibility of Hickam Air Force Base (AFB) personnel to determine the best schedule for filter cleaning and/or replacement depending on the results of the initial observations.

The filter can be checked after turning off the blower system. To remove the filter, loosen the clamps, lift the metal top off of the air filter, and lift the air filter from the metal housing. When replacing the filter, be careful to ensure that the rubber seals remain in place. ES has provided Hickam AFB with a supply of air filters for the next year of blower operation. Should additional air filters be required, they can be ordered from Solberg Manufacturing, Inc. in Itasca, Illinois. Their phone number is (708) 773-1363. It is recommended that Hickam AFB keep a spare air filter at each site.

3.0 BLOWER PERFORMANCE MONITORING

To monitor the blower performance, vacuum, pressure, and temperature must be measured. These data should be recorded on the data collection sheets provided. All measurements will be taken at the same time while the system is running.

3.1 Pressure/Vacuum

Open the shed roof and record the pressure and vacuum readings directly from the gauges in inches of water. Pressure readings are necessary to determine design parameters, and to verify that the blower is operating correctly. Vacuum readings are necessary to assure that the filter is clean. Record the measurements on the data collection sheet provided.

3.2 Temperature

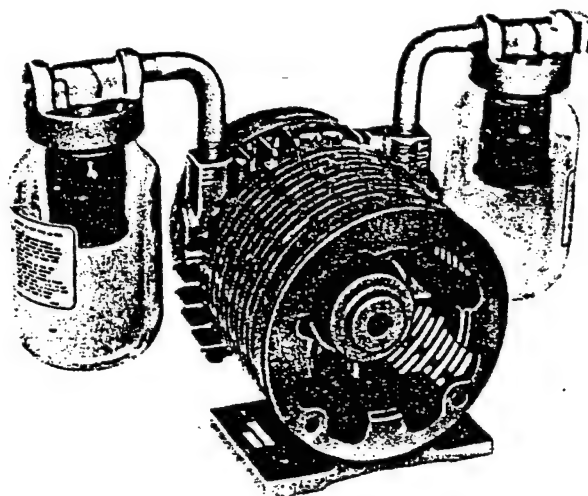
Open the shed roof and record the temperature readings directly from the gauges in degrees Fahrenheit. Record the measurements on the data collection sheet provided. Temperature readings are necessary to verify that the blower is operating correctly. The temperature should remain relatively constant with time. Should the temperature rise substantially in a short period of time, a problem may exist within the blower. Ambient air temperature fluctuations will affect the temperature readings but the temperature rise across the blower should not vary by more than 20°F.

4.0 MONITORING SCHEDULE

The following monitoring schedule is recommended for this system. During the initial months of operation, more frequent monitoring is recommended to ensure that any start up problems are quickly corrected. Data collection sheets have been provided for use by Hickam AFB personnel during data collection.

<u>Monitoring Item</u>	<u>Monitoring Frequency</u>
Blower vacuum and temperature	Weekly.
Filter change	As required. When vacuum across filter exceeds 15 inches of water.

Oilless 1067, 2067, 2567 Series



MODEL 1067 SERIES
26" HG MAX. VAC., 8.50 CFM OPEN FLOW

MODEL 2067 SERIES
27" HG MAX. VAC., 17.00 CFM OPEN FLOW

MODEL 2567 SERIES
27" HG MAX. VAC., 21.00 CFM OPEN FLOW

PRODUCT FEATURES

- Oilless operation
- Close coupled/easy motor mounting
- Rugged construction/low maintenance
- Essentially pulse free service

INCLUDES

- Filter AA800C (1067), AA900D (2067/2567)
- Muffler AA800F (1067), AA900F (2067/2567)
- Fan/coupling assembly AH198
- Fan guards AC102C, AH194

RECOMMENDED ACCESSORIES

- Vacuum relief valve AA840A (1067), AA308 (2067/2567)
- Vacuum relief valve AA308B (2067/2567)
- Vacuum gauge AA640
- Vacuum gauge AA640C
- Repair kit K356 (1067)
- Repair kit K350 (2067/2567)

Important Notice:

Pictorial and dimensional data is subject to change without notice.

EUROPEAN MODEL

Product Dimensions Metric (mm)

Model	A	B	C	D	E	F	G	H	I	J	K	L
1067	429	213	240	254	102	11	125	165	241	142	19	80
2067	449	229	315	333	102	11	124	165	284	164	19	80
2567	449	229	315	333	102	11	125	165	284	164	19	80

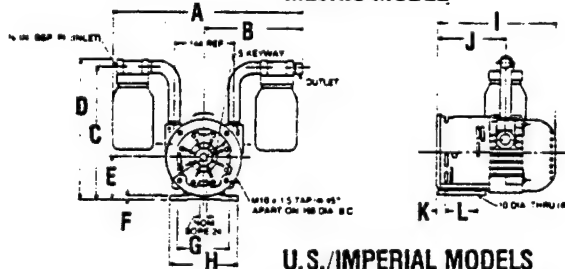
U.S. MODEL

Product Dimensions Metric (mm) U.S. Imperial (inches)

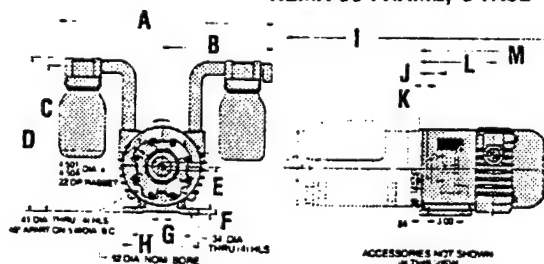
Model	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1067	429	213	240	254	102	11	124	165	454	-	-	142	241	76	21
1067	16.88	8.40	9.44	10.0	4.0	.44	4.88	6.5	17.88	-	-	5.59	9.50	3.00	.84
2067	449	229	315	333	102	11	124	165	540	56	18	164	284	76	21
2067	17.69	9.0	12.42	13.12	4.0	.44	4.88	6.5	21.25	2.19	.69	6.44	11.19	3.00	.84
2567	449	229	315	333	102	11	124	165	540	56	18	164	284	76	21
2567	17.69	9.0	12.42	13.12	4.0	.44	4.88	6.5	21.25	2.19	.69	6.44	11.19	3.00	.84

Dimensions for reference only.

METRIC MODEL



U.S./IMPERIAL MODELS NEMA 56 FRAME, C FACE



INLET
2067/2567 3/4 IN. BSP.
1067 1/2 IN. BSP.

INLET
2067/2567 3/4 NPT
1067 1/2 NPT

Product Specifications

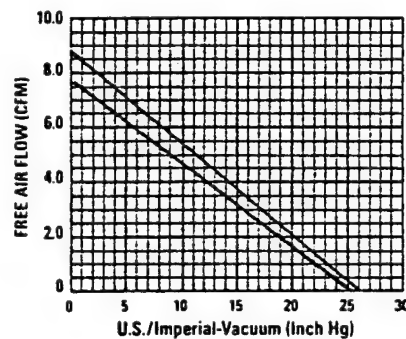
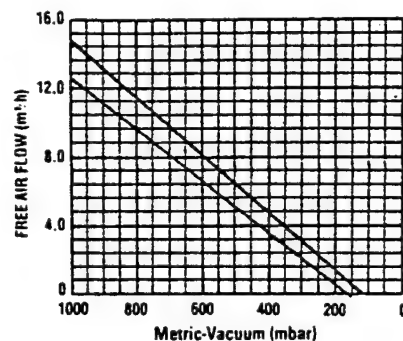
Model Number	Motor	RPM		HP	kW	Net Wt.	
		60 cycle	50 cycle			lbs.	kg
1067-V103	Not included	1725	1425	1/2	0,37	37	16,82
1067-V105 (metric)	Not included	1725	1425	1/2	0,37	37	16,82
1067-V107-G483X (like 1067-V103 plus motor)	115/230-60-1	1725	—	1/2	0,37	79	35,91
2067-V103	Not included	1725	1425	1	0,75	55	25,00
2067-V105 (metric)	Not included	1725	1425	1	0,75	55	25,00
2067-V107-G468X (like 2067-V103 plus motor)	115/230-60-1	1725	—	1	0,75	84	38,18
2567-V103	Not included	1725	1425	1½	1,1	49	22,27
2567-V105 (metric)	Not included	1725	1425	1½	1,1	49	22,27
2567-V107-G471 (like 2567-V103 plus motor)	230/460-60-3	1725	—	1½	1,1	91	41,36
*2567-V105-CC110-1	220/240-380/415-50-3	—	1410	1½	1,1	93	42,00

* Available only in Europe.

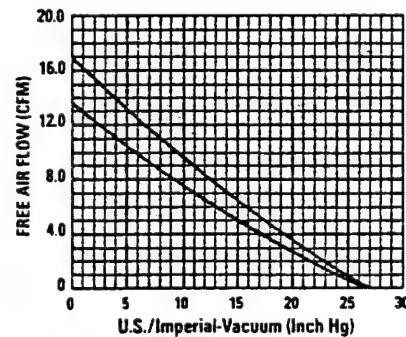
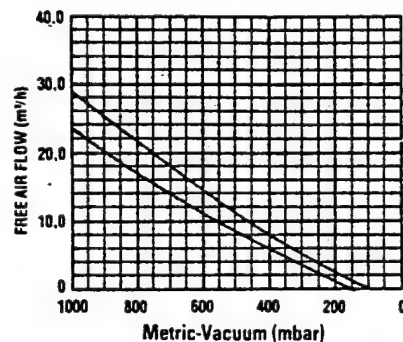
Product Performance (Metric U.S. Imperial)

Black line on curve is for 60 cycle performance.
Blue line on curve is for 50 cycle performance.

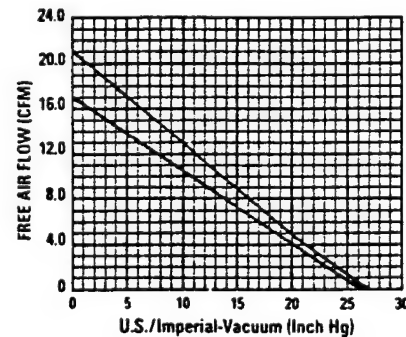
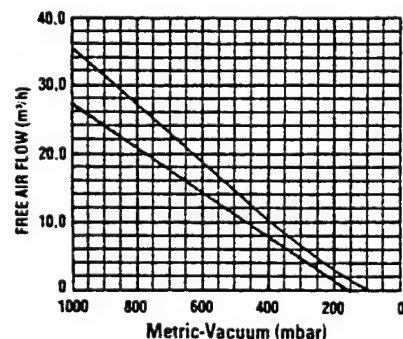
Model 1067



Model 2067

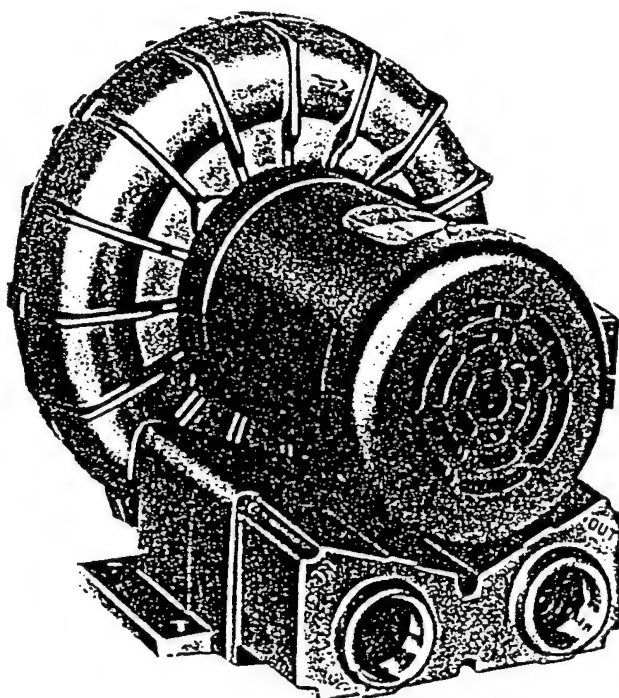


Model 2567



SITE: _____

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MODEL R5325A-2
60" H₂O MAX. VAC., 145 CFM OPEN FLOW

PRODUCT FEATURES

- Oilless operation
- TEFC motor mounted
- Can be mounted in any plane
- Rugged construction: low maintenance

COMMON MOTOR OPTIONS

- 115/208-230V, 60 Hz, single phase
- 208-230/460V, 60 Hz; 190-220/380-415V, 50 Hz, three phase
- 575V, 60 Hz, three phase

RECOMMENDED ACCESSORIES

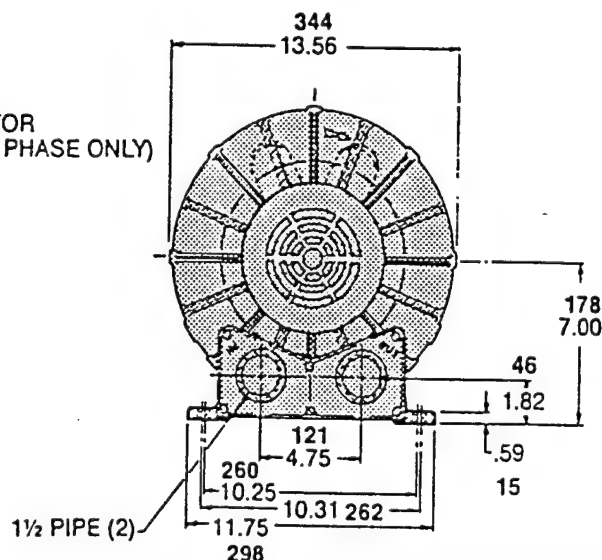
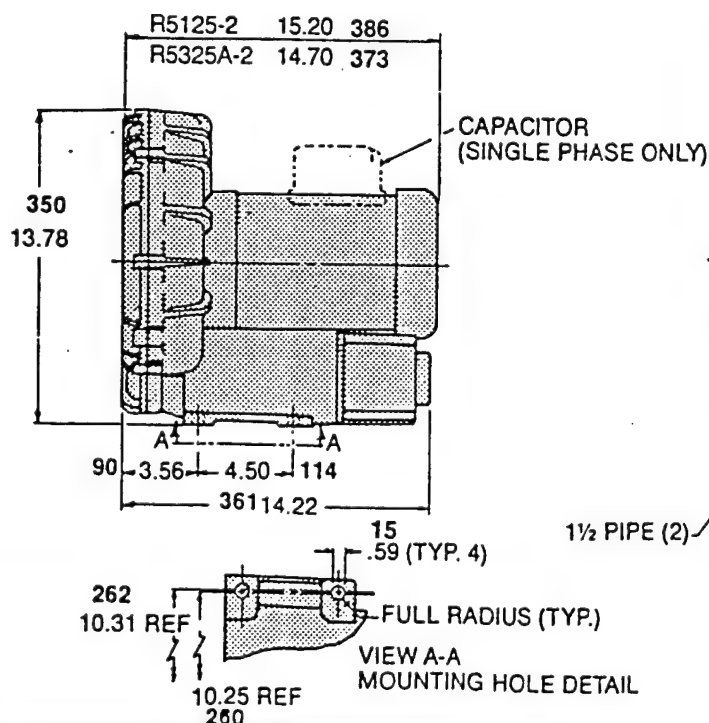
- Vacuum gauge AJ497
- Automotive-type filter AG337
- Muffler AJ121D
- Relief valve AG258

Various brand name motors are used on any model at the discretion of Gast Mfg. Corp.

Important Notice:

Pictorial and dimensional data is subject to change without notice.

Product Dimensions Metric (mm) U.S. Imperial (inches)

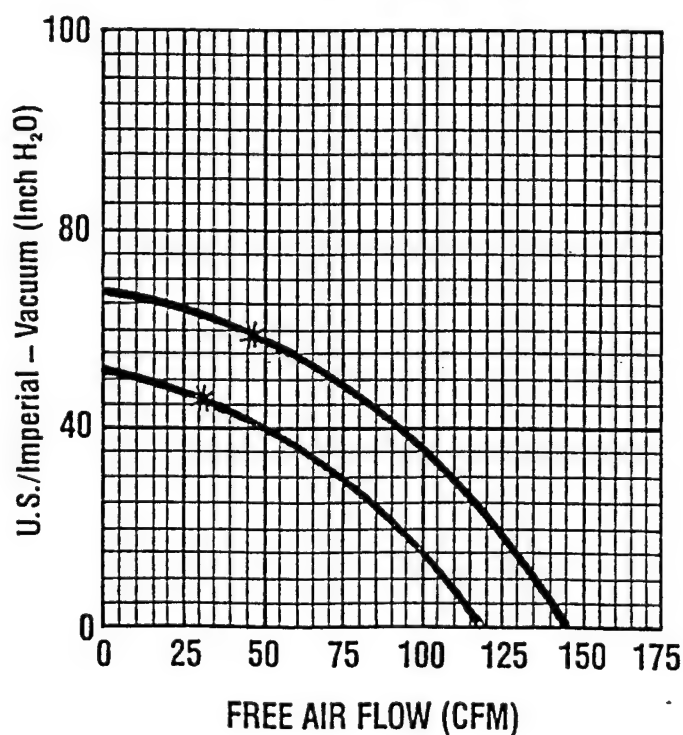
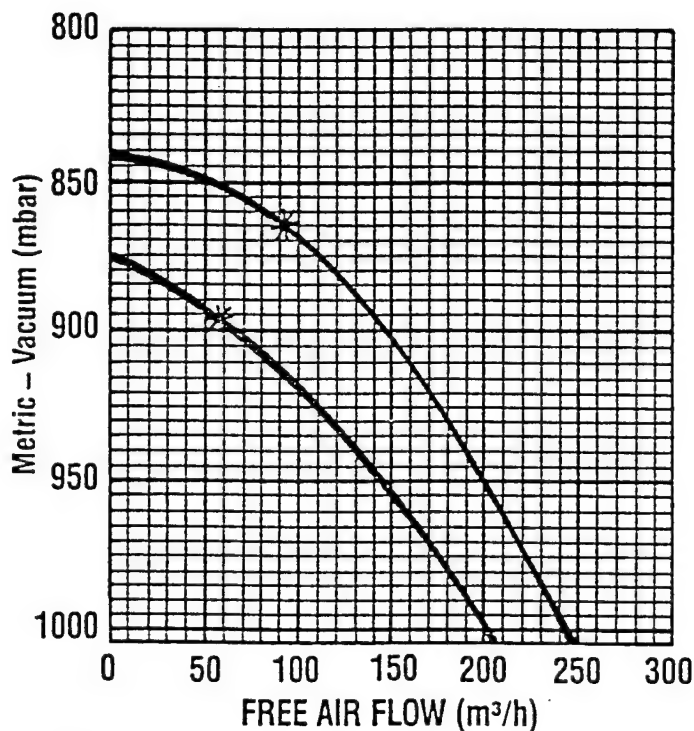


Product Specifications

Model Number	Hz	Motor Specs	HP	RPM	Max Vac		Max Flow		Net Wt.	
					"H ₂ O	mbar	cfm	m ³ /h	lbs.	kg
R5325A-2	50	190-220/380-415-50-3	1.35	2850	47	897	120	204	65	29,5
	60	208-230/460-3	2.5	3450	60	865	145	246		
R5125-2	60	115/208-230-60-1	2.5	3450	60	865	145	246	65	29,5

Product Performance (Metric U.S. Imperial)

Black line on curve is for 60 cycle performance.
Blue line on curve is for 50 cycle performance.



*Minimum flow permissible through the unit for trouble-free, continuous operation.

SITE: _____

[illegible]

APPENDIX B

GEOLOGIC BORING LOGS
AND
CHAIN-OF-CUSTODY FORMS

PROJECT:

LOCATION ID: *H-I-H-VW*

LOG OF BORING:

DATE STARTED: *3/22/93*GEOLOGIST/ENGINEER: *CRAIG MILLER / JOHN RATZ*DATE COMPLETED: *3/22/93*

NOTES:

DRILLING METHOD: *HSA*BOREHOLE DIAMETER: *10.5" OD*SAMPLING METHOD: *SPLIT SPOON*SURFACE CONDITIONS: *75°F, partly cloudy, grass surface*DRILLER: *GeoLABS*

DEPTH (FEET)	SAMP. NO.	SAMPLE	BLOWS/6"	DRIVEN/ RECOV.	STRAT. COLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE		NOTES
								USCS	LC	
1						1; <u>CLAY AND SAND</u> - 50% clay 50% SAND; BROWN. well sorted. DRY.				
2						No odor or staining (1-2' Bgs)				
3						2; <u>CORALLINE RUBBLESTONE AND SAND</u> (2-3' Bgs)				2.1 ppm Ambient
4						50% CORAL 50% SAND				1.7 ppm baggie HOSP with micro tip
5						3; <u>CLAY AND VOLCANIC TUFF</u> - 65% CLAY				
6						25% TUFF 10% CORAL. Greyish Brown.				
7						Poorly sorted. DRY. No odor or staining (3-7)				
8						7; <u>SILTSTONE</u> with SAND. 75% stone,				
9						25% SAND. Light Brown Grey. HARD.				0.0 ppm Ambient
10						Poorly sorted. Slightly moist, No odor or staining (7-11' Bgs)				32.0 ppm baggie HOSP w/HC Analyzer
11						11; <u>Cemented SAND</u> . (Sandstone) Dark Grey				↓
12						Aphanitic < 1mm. moist. No odor or staining (11-15' Bgs)				
13										0.0 ppm Ambient
14										38 ppm baggie HOSP
15						15; <u>CLAYISH SAND</u> . BROWN. well sorted. SAND is very fine grained. moist. No odor or staining (15-20' Bgs)				* odor detected @ 18' Bgs (Hydrocarbon)
16										* 19' possible Basalt in cuttings
17										
18										
19										
20										0.0 ppm Ambient
21										1600 ppm baggie HOSP
22										
23										
24										
25										
26										
27										
28										
29										
30										

PROJECT:

LOCATION ID: *HI-H-MPA*

LOG OF BORING:

DATE STARTED: *3-23-93*GEOLOGIST/ENGINEER: *Craig Miller / John Ratz*DATE COMPLETED: *3-23-93*

NOTES:

DRILLING METHOD: *ASA*BOREHOLE DIAMETER: *8" O.D.*SAMPLING METHOD: *SPLIT SPOON*SURFACE CONDITIONS: *75°F, Partly cloudy, grass surface*DRILLER: *GeolABS*

DEPTH (FEET)	SAMP. NO. SAMPLE	BLOWS/6"	DRIVEN/ RECOV.	STRAT. COLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE USCS	LC	NOTES
1					1' <u>CLAY AND SAND</u> - 50% clay 50% SAND. Some organics. Brown. Well sorted, dry. No odor or staining.				FAST Drilling
2									
3									
4					2' <u>CORALLINE RIBBLE</u> stone and clay (0-2' BGS)				
5					5' <u>CLAYSTONE</u> - argillite, mafic, angular fragmentation. Very hard. Dry BUT moistening with depth. No odor or staining. (5-11' BGS)				0.0 ppm Ambient 45.3 ppm baggie HOSP
6									
7									
8									
9									
10									
11					11' <u>SANDSTONE</u> - Brown. Angular and laminar fragmentation. Very hard. Slightly moist. No odor or staining. (11-16' BGS)				0.1 ppm Ambient 253 ppm baggie HOSP
12									
13									
14									
15									
16					16' <u>CLAY</u> - Dark Grey. moderate plasticity, stiffness, stickiness. moist. No odor or staining.				0.2 ppm Ambient 153 ppm baggie HOSP
17									
18					17' <u>BASALT</u> - Dark Grey Brown. mafic phenocrysts. Angular fragmentation. Dry. No odor or staining. non vesicular (17-18' BGS)				* odor Detected @ 18' BGS
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									

PROJECT:

LOCATION ID: HI-A-MPB

LOG OF BORING:

DATE STARTED: 3/23/93GEOLOGIST/ENGINEER: CRAIG MILLER / John RATEDATE COMPLETED: 3/23/93

NOTES:

DRILLING METHOD: HSABOREHOLE DIAMETER: 8" ODSAMPLING METHOD: SPLIT SPOONSURFACE CONDITIONS: 85°F, SUNNY, GRASS SURFACE.DRILLER: GEOLABS

DEPTH (FEET)	SAMP. NO. SAMPLE	BLOWS/6" DRIVEN/ RECOV.	STRAT. COLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE		NOTES
						USCS	LC	
1				1' CLAY WITH SAND - 65% CLAY 35% SAND. moderately sorted. Low plasticity, stickiness, high stiffness.				First Drilling
2				Dry. No odor or staining (0-2' Bgs)				↓
3				2' CORALLINE RUBBLESTONE and clay.				0.0 ppm Ambient
4				50% CORAL 50% clay. moderately sorted, DRY (2'-3.5' Bgs)				453 ppm baggie NDSP
5	X	4"		3.5' CLAYSTONE - mafic, argillite appearance. Angular Fragmentation very dry. No odor or staining. (3.5-11' Bgs)				↓
6								
7								
8								
9								
10								
11	X	6"		11' SILT/SANDSTONE - GREYISH BROWN. Angular Fragmentation. "few" mafic minerals present. Calcite in fractures. Slightly moist. No odor or staining. (11-17' Bgs)				0.0 ppm Ambient
12								152 ppm baggie NDSP
13								↓
14								
15								
16								0.0 ppm Ambient
17	X	8"		17' BASALT - DARK GREY BROWN. w/ mafic phenocryst, mostly micro-crystalline. nonvesicular. No odor or staining. (17-18' Bgs), moist				2272 ppm baggie NDSP
18								* @ 18' Bgs
19								Detected Hydrocarbons
20								odor and staining
21								in cuttings
22								
23								
24								
25								
26								
27								
28								
29								
30								

TDBGS @
18' Bgs

PROJECT: LOCATION ID: <i>142-H-MPC</i>		LOG OF BORING:	
DATE STARTED: <i>3-24-93</i>		GEOLOGIST/ENGINEER: <i>CRAIG MILLER/JOHN RATTZ</i>	
DATE COMPLETED: <i>3-24-93</i>		NOTES:	
DRILLING METHOD: <i>HSA</i>		BOREHOLE DIAMETER: <i>8" 00</i>	
SAMPLING METHOD: <i>SPLIT SPOON</i>		SURFACE CONDITIONS: <i>70°F, partly cloudy, grass surface</i>	
DRILLER: <i>GeolABS</i>			

DEPTH (FEET)	SAMP. NO. SAMPLE	BLOWS/6"	DRIVEN/ RECOV.	STRAT. COLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE USCS	LC	NOTES
1					1'; clay with sand 75% clay 25%				FAST
2					sand, poorly sorted. clay has low				Drilling
3					plasticity, stickiness, high stiffness, DRY				↓
4					Dry. no odor or staining. Laminar				0.0 ppm Ambient
5					Bedding with fractures (0-2' Bgs)				253 ppm baggie NOSP
6					2'; coralline rubblestone and clay				
7					50% coral 50% clay, moderately				
8					sorted, DRY. no odor or staining.				
9					(2-3' Bgs)				
10					3'; claystone - mafic, argillite, angular				
11					fragmentation. very DRY. no odor				
12					OR staining. (3-11.5' Bgs)				
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									

PROJECT:

LOCATION ID: HZ-K-VW-9

LOG OF BORING:

DATE STARTED: 3/24/93

GEOLOGIST/ENGINEER: Craig Miller / John Ratz

DATE COMPLETED: 3/24/93

NOTES: 1300 hrs

DRILLING METHOD: HSA

BOREHOLE DIAMETER: 10.5"

SAMPLING METHOD: Split Spoon 24"

SURFACE CONDITIONS: GRASS Flat LANDS, Partly,

DRILLER: Geolabs

Cloudy / 80°F

DEPTH (FEET)	SAMP. NO. SAMPLE	BLOWS/6" DRIVEN/ RECOV.	STRAT. COLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE		NOTES
						USCS	LC	
1				CORALLINE Rubblestone and CORAL				MODERATE Drilling RATE ↓ 0.0 Ambient Air
2				SAND. 50% Rubblestone 50% SAND.				
3				VERY PALE BROWN 10 YR, 8/3. Porous				
4				3" Hemispherical (1/4" - 1 1/2"), DRY, NO STAINING				
5				well sorted (0-5' Bgs)				
5				* odor detected @ ~ 4.5'				3290 ppm baggie * WATER Detected @ 9' Bgs
6	33	24"		5' CLAY AND CORAL 50% clay 50% CORAL, moist				
7	35			6' CLAY with CORALLINE Rubblestone				
8	18			75% CLAY 25% CORAL. Light olive gray				
9	23			5Y, 6/2. Poorly sorted. clay has low				
10				Plasticity, moderate stiffness and				
11				stickiness, moist, odor, No staining				
12				(6'-9' Bgs)				
13				TDRGS @ 9'				
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								

PROJECT:

LOCATION ID: HI-K-MPA-6

LOG OF BORING:

DATE STARTED: 3/24/93

GEOLOGIST/ENGINEER: Craig Miller / John Ratz

DATE COMPLETED: 3/24/93

NOTES: 1430 hrs

DRILLING METHOD: HISA

BOREHOLE DIAMETER: 8"

SAMPLING METHOD: Split Spoon 24"

SURFACE CONDITIONS: Flat Grass lands, partly cloudy

DRILLER: GEOLABS

80°F

DEPTH (FEET)	SAMP. NO. SAMPLE	BLOWS/6" DRIVEN/ RECOV.	STRAT. COLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE		NOTES
						USCS	L C	
1				CORALLINE RUBBLESTONE and CORAL				FAST Drilling ↓
2				Sand. 50% Rubblestone, 50% Sand				
3				Very pale brown to yr, 8/3. Porous				
4				and Hemispherical, (1/2"-1 1/2") Dry, no				
5				staining, well sorted				
6				(0-4' Bgs)				
7				4'; clay and coral, 50% clay 50% coral, moist				* Detected Hydrocarbon odor @ ~ 4.5'
8				(4-5' Bgs)				
9				5'; clay with coralline rubblestone				
10				75% clay 25% coral. Light olive gray				
11				SY, 6/2. Poorly sorted. clay has low				
12				plasticity, moderate stiffness and				
13				stickiness. moist odor, no staining				
14				(5-6' Bgs)				
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								

TDRGS @ 6'

PROJECT:

LOCATION ID: HI-K-MPB-6

LOG OF BORING:

DATE STARTED: 3/25/93

GEOLOGIST/ENGINEER: CRAIG MILLER, JOHN RATZ

DATE COMPLETED: 3/25/93

NOTES: 0810 hrs

DRILLING METHOD: HSA

BOREHOLE DIAMETER: 8"

SAMPLING METHOD: Split Spoon 24"

SURFACE CONDITIONS: GRASS Flat LANDS, SUNNY, 70°F

DRILLER: GEOLABS

DEPTH (FEET)	SAMP. NO.	SAMPLE BLOWS/6"	DRIVEN/ RECOV.	STRAT. COLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE		NOTES
							USCS	L C	
1					CORALLINE Rubblestone and CORAL				Fast Drilling ↓ * odor detected @ 4.0' Bgs 0.0 ppm Ambient air 3342 ppm baggie
2					SAND. 50% Rubblestone, 50% SAND				
3					Very pale brown 10YR 8/3 Porous				
4					And hemispherical, (1/2" - 1 1/2") DRY,				
5					No staining, well sorted				
6					(0-4' Bgs)				
7					4' CLAY AND CORAL 50% clay 50% CORAL, moist				
8					(4-5' Bgs)				
9					5' CLAY WITH CORALLINE Rubblestone				
10					75% clay 25% CORAL, light olive gray				
11					SY, 6/2, poorly sorted. clay has low				
12					plasticity, moderate stiffness and				
13					stickiness. moist, odor, no staining				
14					(5-6' Bgs)				
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									

TDRGS @ 6'

PROJECT:

LOCATION ID: HI-K-MPC-6

LOG OF BORING:

DATE STARTED: 3/25/93

GEOLOGIST/ENGINEER: CRAIG MILLER, JOHN RATZ

DATE COMPLETED: 3/25/93

NOTES: 0930 hrs

DRILLING METHOD: HSA

BOREHOLE DIAMETER: 8"

SAMPLING METHOD: SPLIT SPOON 24"

SURFACE CONDITIONS: GRASS FLAT LANDS, SUNNY, 75°F

DRILLER: GEOLABS

DEPTH (FEET)	SAMP. NO. SAMPLE	BLOWS/6" DRIVEN/ RECOV.	STRAT. COLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE		NOTES
						USCS	LC	
1				CORALLINE RUBBLESTONE AND CORAL SAND. 50% RUBBLESTONE, 50% SAND, VERY				FAST Drilling ↓ - Lost most of split spoon sample - 0.0 ppm Ambient air 677 ppm baggie * odor detected @ 4.5' Bgs
2				PALE BROWN 10 YR, 8/3 Porous and				
3				HEMISPHERICAL. ($\frac{1}{2}$ " - $1\frac{1}{2}$ ") DRY, NO				
4				STAINING, well sorted.				
5		57		(0-3.5' Bgs)				
6		50		3.5' CORAL and CLAY. 60% CORAL, 40% CLAY, moist				
7				(3.5-4.5' Bgs)				
8				4.5' CORALLINE RUBBLESTONE AND CORAL				
9				SAND. 60% CORAL 40% SAND. LIGHT				
10				BROWNISH GRAY, 10 YR, 6/2. CORAL IS NOT				
11				VERY POROUS, HEMISPHERICAL ($\frac{1}{2}$ " - $1\frac{1}{2}$ ")				
12				SLIGHTLY MOIST. ODOR, NO STAINING,				
13				moderately sorted.				
14				(4.5-5.5' Bgs)				
15				5.5' CORAL WITH CLAY, 70% CORAL, 30%				
16				CLAY. LIGHT OLIVE GRAY 5Y 6/2. Porous				
17				and Hemispherical. ($\frac{1}{4}$ " - 1"). moist,				
18				odor, no staining. poorly sorted.				
19				(5.5-6.0' Bgs)				
20				TDBG5 @ 6'				
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								

PROJECT:

LOCATION ID: SITE Z Vent Well

LOG OF BORING:

DATE STARTED: 3-30-93

GEOLOGIST/ENGINEER: CRAIG A. MILLER / JOHN RÄTZ

DATE COMPLETED: 4-1-93

NOTES:

DRILLING METHOD: VSA

BOREHOLE DIAMETER: 10.5"

SAMPLING METHOD: SPLIT SPOON

SURFACE CONDITIONS: 85°F, SUNNY, GRASS & ASPHALT

DRILLER: GEOLABS

DEPTH (FEET)	SAMP. NO. SAMPLE	BLOWS/6" DRIVEN/ RECOV.	STRAT. COLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE		NOTES
						USCS	L C	
1				1'; Silt with clay and coral fragments				FAST Drilling ↓
2				1.5"-3" some organics, dark brown				
3				Loosely Consolidated. No odor or				
4				staining. DRY				
5				4'; Silt with clay and coral fragments				
6				1/4 - 1/2" SAA				* Soil becoming moist @ 5' BGS * END OF CORAL @ 7' BGS 0.0 ppm Ambient 19.6 ppm baggie HOSP - CUTTINGS coming up very blacky - sticky texture
7								
8								
9								
10				9'; Silt with clay, dark rusty red				
11				well consolidated. Very moist. No				0.0 ppm Ambient 69.5 ppm baggie HOSP * @ 21' Ammonia odor detected @ 25' Drilling RATE slowing DOWN
12				staining or odor. Some wood				
13				fragments				
14								
15								
16								0.0 ppm Ambient 69.5 ppm baggie HOSP * @ 21' Ammonia odor detected @ 25' Drilling RATE slowing DOWN
17								
18				19'; Saprolite - light orange brown				
19				with multicolored minerals. olivine				
20				and secondary calcite. Vesicular				
21				1-2mm. moderately consolidated				0.0 ppm Ambient 1286 ppm baggie HOSP
22				moist. No odor or staining.				
23								
24								
25								
26								0.0 ppm Ambient 1286 ppm baggie HOSP
27								
28								
29				29'; Saprolite - med brown with				
30				some orange weathered patches. Blacky				
				light, vesicular. Very moist. odor				
				and some black staining present				

PROJECT:
LOCATION ID: Site Z - Vent Well

LOG OF BORING:

DEPTH (FEET)	SAMP. NO. SAMPLE	BLOWS/6" DRIVEN/ RECOV.	STRAT. COLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE USCS	LC	NOTES
31			↑					
2			S					
3			A					
4			P					
5			R					
6			O					
7			L					
8			I					
39		12"	T	39'; <u>Saprolite</u> - Dark Brown and Black. Very homogenous. moderately Consolidated. Slight, vesicular (1-2mm). Very moist. odor and Black staining present				0.0 ppm Ambient 4,726 baggie NOSP
40			↓					- Cuttings coming up slow
1								
2								
3								
4								
5								
6								
7								
8								
9		12"		49'; <u>Saprolite</u> - SAA				* 49' very strong odor
56								
1								
2								* Found water @ 52' Bgs
3								
4								
5								- Cuttings not coming out of hole. must be saturated & sticking to auger
6								
7								
8								
59		24"		59'; <u>Saprolite</u> - Dark Brown. Approx. 10% Sand. moderately Consolidated. Non vesicular. Very moist. odor but no staining				0.0 ppm Ambient 1,800 ppm baggie NOSP
60								

NOTES:

PROJECT:

LOCATION ID: Site 2 - Vent well

LOG OF BORING:

DEPTH (FEET)	SAMP. NO. SAMPLE	BLOWS/6"	DRIVEN/ REC'D.	STRAT. COLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE USCS	LC	NOTES
1									
2									- Cuttings slowly coming out of hole
3									
4									
5									- Slow Drilling
6									↓
7	⊗ ?	12"			69'; <u>Saprolite</u> - olive green with red patches. very consolidated. Low moisture. Slight odor and no staining.				0.0 ppm Ambient 1200 ppm baggie NOsp
8									
9									
70									
1									Slow Drilling
2									↓
3									
4									
5									
6									
7									
8									@ 77' Cuttings became very wet and clay in texture.
9	⊗ ?	12"			79'; <u>Saprolite</u> . olive Brown. Hard and well consolidated. Slightly vesicular. moist. mod. odor, no staining.				0.1 ppm Ambient 1286 ppm baggie NOsp
80									
1									
2									
3									
4									Slow Drilling
5									↓
6									
7									
8									
9	⊗ ?	12"			89'; <u>Saprolite</u> - medium Brown. Hard, very <u>vesicular</u> (2-7mm) Fractures easily, moist slight odor, mineral staining				0.0 ppm Ambient 685 ppm baggie NOsp
90									

NOTES:

PROJECT:

LOCATION ID: SITE 2 - Vent. well

LOG OF BORING:

DEPTH (FEET)	SAMP. NO.	SAMPLE	BLOWS/6"	DRIVEN/RECOV.	STRAT. COLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE		NOTES
								USCS	L C	
1										
2										Slow
3										Drilling
4										↓
5										-Cutting still
6										Coming up
7										vert.
8										
9										
100										
1										
2										0.0 ppm Ambient
3										757 ppm baggie NOSP
4										- Drilled an
5										extra 2 feet
6										For RAT hole
7										
8										
9										
1										
2										
3										
4										
5										
6										
7										
8										
9										

NOTES:

PROJECT:

LOCATION ID: NI-2-MPA

LOG OF BORING:

DATE STARTED: 4-15-93

GEOLOGIST/ENGINEER: C. Miller, J. Ruff

DATE COMPLETED: 4-16-93

NOTES:

DRILLING METHOD: NSA

BOREHOLE DIAMETER: 10 1/4"

SAMPLING METHOD: Split Spoon

SURFACE CONDITIONS: asphalt and grass

DRILLER: BelAES

DEPTH (FEET)	SAMP. NO. SAMPLE	BLOWS/6" DRIVEN/ RECOV.	STRAT. COLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE		NOTES
						USCS	LC	
1				0-2" Black Asphalt grading into				FAST Drilling ↓
2				Reddish Brown Silt and organics.				
3				Coral fragments 3/4" - 1 1/2"				
4								
5								
6								* END OF CORAL @ 5'
7								↓
8								- @ 8' Auger Began to move horizontally
9								
10				10' Silt with clay, Dark Rusty Red.				0 ppm Ambient
11				Well consolidated, very homogeneous				14 ppm HDSp Baggie
12				texture. Very moist, no staining				
13				or odor.				↓
14								
15								- @ 15' cuttings became very blocky.
16								- @ 15-17' drilling became very easy
17								
18								
19								
20				20' Saprolite, very Dark Rusty Brown.				- 0 ppm Ambient
21				With some weathered patches, blocky, non-				- 260 ppm baggie HDSp
22				vesicular. very moist, no staining but				- @ 20' noticed evidence of water could be only a lens or saturated soil.
23				strong Hydrocarbon odor.				
24								- 22' drilling slowed down due to wet cuttings
25								
26								
27								
28								- @ 28' easy drilling again
29								
30				See next page for 30' sample				- Auger walked about 1.5' horizontally since 8' BGS

PROJECT:
LOCATION ID: N1-2-MPA

LOG OF BORING:

DEPTH (FEET)	SAMP. NO. SAMPLE	BLOWS/6" DRIVEN/ RECOV.	STRAT. COLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE		NOTES
						USCS	LC	
31	X	75	6"	31'; <u>Saprolite</u> . Dark Brown with weathered orange patches, well consolidated, very vesicular, black staining with very strong odor, moist.				0 ppm Ambient 2300 ppm baggie HDSP ↓ moderate Drilling Speed ↓
2								
3								
4								
5								
6								
7								
8								
9								
40								
1	X	11	24"	40'; <u>Saprolite</u> - Dark Brown to black very homogeneous, moderately consolidated vesicular (1-4mm). Complete black staining with very strong odor, moist.				0 ppm Ambient 1800 ppm baggie HDSP ↓ - Drilling Slow Because of wet cuttings ↓
2		14						
3		17						
4		19						
5								
6								
7								
8								
9								
50								
1	X	5	24"	50'; <u>Saprolite</u> . Orangish Brown with red weathered patches, moderately consolidated slightly vesicular, no staining but some odor of solvent, moist.				0.0 ppm ambient 440 ppm baggie HDSP ↓ Slow Drilling ↓
2		7						
3		10						
4		13						
5								
6								
7								
8								
9								
60								

NOTES: HDSP = Head Space

PROJECT:
LOCATION ID: H1-2-MPA

LOG OF BORING:

DEPTH (FEET)	SAMP. NO. SAMPLE	BLOWS/6" DRIVEN/ RECOV.	STRAT. COLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE		NOTES
						USCS	LC	
1								Drilling still
2								slow. wet cuttings
3								are difficult
4								to identify
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
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31								
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90								
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92								
93								
94								
95								
96								
97								
98								
99								
100								

NOTES:

PROJECT: LOCATION ID: <i>14Z-2-141B</i>		LOG OF BORING:	
DATE STARTED: <i>4-9-93</i>		GEOLOGIST/ENGINEER: <i>C. MILLER, J. ROY</i>	
DATE COMPLETED: <i>4-13-93</i>		NOTES:	
DRILLING METHOD: <i>NSD</i>		BOREHOLE DIAMETER: <i>10 1/2" 0-60, 8" 6-75</i>	
SAMPLING METHOD: <i>Split Spoon</i>		SURFACE CONDITIONS: <i>grass and asphalt</i>	
DRILLER: <i>Leola BS</i>			

DEPTH (FEET)	SAMP. NO.	SAMPLE	BLOWS/6"	DRIVEN/ RECOV.	STRAT. COLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE		NOTES
								USCS	LC	
1						9' silt with clay and coral fragments				Fast Drilling
2						1.5"-3". some organics, loosely				
3						consolidated, no odor or staining (0-1 bags)				
4						Dark Brown in color, dry				
5						1' silt with clay and coral fragments				
6						1/2"-1". SRA otherwise from 1-10'gs				
7										
8										
9										
10										
11						10' silty clay with some weathered				*END OF CORAL
12						minerals. Conglomerated texture,				2 ppm Ambient
13						blocky, Dark Rusty Brown w/orange				9 ppm Baggie NOSP
14						weathered minerals, no odor or				
15						staining, slightly moist.				Fast Drilling
16										
17										
18										
19										-18' noticed color
20										change to lighter
21										Brown
22										
23										0 ppm Ambient
24										3 ppm Baggie NOSP
25										
26										Drilling slowed
27										down a little
28										
29										
30										29' first odor
										detected

See next page for 30'-31' sample

PROJECT:
LOCATION ID: H1-2-MPB

LOG OF BORING:

DEPTH (FEET)	SAMP. NO. SAMPLE	BLOWS/6" DRIVEN/ RECOV.	STRAT. COLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE		NOTES
						USCS	LC	
31	X	13	12"	31'; Saprolite, Reddish Brown with orange and red weathered patches, blocky and moderate consolidation. Vesicular, no staining. Slight solvent odor, slightly moist.				0 ppm Ambient 100 ppm Baggie H2Sp - @ 30' color change from dark brown to reddish color ↓ FAST Drilling again ↓
39								
40	X	23	12"	40'; Saprolite, Highly weathered to a clay texture. Rusty Red Brown with few yellow patches. Very consolidated. Blocky, non vesicular, slightly moist, odor present, no staining				0 ppm Ambient 240 ppm Baggie H2Sp ↓ FAST Drilling ↓
1		70						
2								
3								
4								
5			grout					
6								
7								
8								
9								
50	X	6	24"	50'; Saprolite, Dark Rusty Brown, some green weathered patches. Moderately consolidated, clumpy with some horizontal fractures. Slightly vesicular, moist, no staining, little odor.				@ 47'-50' HARD Drilling and stronger Hydrocarbon odor. Possibly due to water @ 48' - WATER encountered 0 ppm Ambient 1800 ppm Baggie H2Sp FAST Drilling ↓
1		13	grout					
2		13						
3								
4								
5								
6								
7			grout					
8								
9								
60								@ 60' - STOP Drilling w/ 1 1/2" outer grout from 60' up to 43'

NOTES:

H2Sp = Head Space

PROJECT:
LOCATION ID: 8/HI-2-MPB

LOG OF BORING:

DEPTH (FEET)	SAMP. NO. SAMPLER	BLOWS/6" DRIVEN/ RECOV.	STRAT. COLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE		NOTES
						USCS	LC	
61								- Drilled through grout from 43'-60' with 8" auger. No water present
2								
3								
4								
5								
6								
7								
8								
9								
70								
1								
2								
3								
4								
75								
6								
7								
8								
9								
1								
2								
3								
4								
5								
6								
7								
8								
9								

NOTES:

PROJECT:

LOCATION ID: SITE 2-MPL

LOG OF BORING:

DATE STARTED: 4-8-93GEOLOGIST/ENGINEER: CRAIG MILLER / JOHN RATZ

DATE COMPLETED:

NOTES:

DRILLING METHOD: NSABOREHOLE DIAMETER: 8"SAMPLING METHOD: SPLIT SPOONSURFACE CONDITIONS: 75°F; Cloudy, asphalt & grassDRILLER: Geolabs

DEPTH (FEET)	SAMP. NO. SAMPLE	BLOWS/6" DRIVEN/ RECOV.	STRAT. COLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE		NOTES
						USCS	LC	
1				2" Black asphalt				
2				1' Silt with clay and coral fragments				
3				1.5"-3.0". Some organic. Rust				
4				Brown. Loosely consolidated. Dry.				- Easy Drilling
5				No odor or staining.				
6				(1'-9' Bgs)				
7								
8								* @ 7' feet coral fragments end.
9				9' Silt with clay. Rust Brown				0.0 ppm Ambient
10				with orange weathered patches.				0.3 ppm baggie HDSP
11				Blocky, moderately consolidated.				
12				Slightly moist. No odor or staining.				
13								
14								
15								* @ 15' color change to dark brown
16								
17								
18								
19				79' clay with silt. - Dark Brown.				0.0 ppm Ambient
20				moderately consolidated. Low plasticity,				0.0 ppm baggie HDSP
21				stickiness, & stiffness. slightly moist.				
22				No odor or staining.				
23								* slight lithology change @ 21' Bgs
24								
25								- Drilling slower
26								
27								
28								
29				29' Saprolite - TAN. moderately				0.0 ppm Ambient
30				consolidated. Blocky. Non vesicular				0.0 ppm baggie HDSP
				Slightly moist. Very sticky. No odor or staining.				

Engineering-Science, Inc.

PROJECT NO.

PROJECT:

LOCATION ID: SITE 2-MPC

LOG OF BORING:

DEPTH (FEET)	SAMP. NO. SAMPLE	BLOWS/6" DRIVEN/ RECOV.	STRAT. COLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE USC	LC	NOTES
31								
2								
3								
4								
5								
6								
7								
8								
9								
40	X	7	12"	39; <u>Saprolite</u> - Reddish Brown, Highly Consolidated. non vesicular clay like texture. slightly moist. No odor or staining.				Drilling easy again ↓ 0.0 ppm Ambient 0.0 ppm baggie HDSP
1								
2								
3								
4								
5								
6								
7								
8								
9								
50	X	7	12"	49; <u>Saprolite</u> - Brownish Black with Red patches. Loosely Consolidated N/A's gritty texture. Saturated. No odor or staining				* WATER FOUND @ 49' BGS -Drilling slowing down ↓ @ 57' cuttings coming up hole
1								
2								
3								
4								
5								
6								
7								
8								
9								
60	X	7	12"	59; <u>Saprolite</u> - TAN, moderately Consolidated. non vesicular. very sticky. slightly moist. No odor or staining				0.0 ppm Ambient 36.8 ppm baggie HDSP

NOTES: HDSP = Headspace

PROJECT:
LOCATION ID: SITE 2-MPC

LOG OF BORING:

DEPTH (FEET)	SAMP. NO. SAMPLER	BLOWS/6"	DRIVEN/ RECOV.	STRAT. COLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE		NOTES
							USCS	LC	
61				S					
2				A					
3									
4				P					
5		X ?	12"	R	64' Saprolite - Dark Rty Brown				0.0 ppm Ambient
6				O	with Black olive patches, moderately				4.3 ppm Enggie NOSP
7				L	consolidated. vesicular (3-6mm),				* LAST split
8				I	slightly moist, no odor or staining				SPoon taken
9				T					@ 64-65' BGS
70				E					
1									
2									
3									
4									
5					TO BGS				
6					@				
7					75'				
8									
9									
1									
2									
3									
4									
5									
6									
7									
8									
9									

NOTES:

PROJECT:

LOCATION ID: *SITE Z - Background*

LOG OF BORING:

DATE STARTED: *J-29-73*GEOLOGIST/ENGINEER: *CRAIG MILLER/JOHN ROTZ*

DATE COMPLETED:

NOTES:

DRILLING METHOD: *USA*BOREHOLE DIAMETER: *8"*SAMPLING METHOD: *SPL. & SPOON*SURFACE CONDITIONS: *SUNNY 80°F, grass lands*DRILLER: *Geolabs*

DEPTH (FEET)	SAMP. NO.	SAMPLE	BLOWS/6"	DRIVEN/ RECOV.	STRAT. COLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE		NOTES
								USCS	LC	
1						1' Clay with silt - 90% clay 10% silt.				FAST Drilling ↓
2						Some organics. Reddish brown, loosely				
3						consolidated. Low plasticity, stickiness,				
4						and stiffness, very dry. No odor or				
5						staining.				
6										
7										
8										
9										
10						6' clay grading to silt. DRY				0.0 ppm Ambient 27.5 ppm Baggie H2Sp
11						SAA				
12										
13										
14										
15										FAST Drilling ↓
16										
17										
18										
19										
20						20' silt and clay; 60% silt 40% clay.				0.0 ppm Ambient 40.1 ppm baggie H2Sp
21						Reddish brown, moderately consolidated				
22						low plasticity, moderate stickiness and				
23						stiffness. DRY. No odor or staining				
24										
25										* Drilling Slowing Down Some Having to Switch gears often ↓
26										
27										
28										
29										
30										

Engineering-Science, Inc.

PROJECT NO.

PROJECT:

LOCATION ID: SITE 2 - Background

LOG OF BORING:

DEPTH (FEET)	SAMP. NO. SAMPLE	BLOWS/6" DRIVEN/ RECOV.	STRAT. COLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE USCS	LC	NOTES
31	X	12"		31'; <u>Silt with clay</u> 65% silt 40% clay. DARK BROWN. moderately consolidated. Blocky. moderate stickiness. NO odor or staining				0.0 ppm Ambient 42.5 ppm baggie H2Sp
2								* Lithology change
3								- Cuttings still coming up slow
4								
5				35'; <u>Saprolite</u> ; Dark Reddish Brown, non vesicular, well consolidated. clay like in lithology, slightly moist NO odor or staining				
6								
7								
8								
9								
40	X	6"		40'; <u>Saprolite-SAN</u> , slightly moist				0.0 ppm Ambient 32.4 ppm baggie H2Sp
1								
2								
3								
4								
5								
6								
7								
8								
9								
50				50'; <u>Saprolite</u> ; SAN, moist				
1								
2								
3								
4								
55								
6								
7								
8								
9								
60								

NOTES:

NID Sp = NIDSPACE

* Cutting NOT
coming out of
hole. Rig does not
have enough
torque. Need to
change Rigs.

PROJECT:

LOCATION ID: SITE-2-Background

LOG OF BORING:

DEPTH (FEET)	SAMP. NO. SAMPLE	BLOWS/6" DRIVEN/ RECOV.	STRAT. COLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE		NOTES
						USCS	LC	
1								
2								
3								
4								
5								
6	X ?	12"	↑	65'; <u>Saprolite</u> -SAA				0.0 ppm ambient 22.1 ppm baggie NDSP
7								
8								
9								
10								Drilling Speed moderate
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21	X ?	12"	↓	80'; <u>Saprolite</u> -SAA				0.0 ppm ambient 13.5 ppm baggie NDSP
22								
23								
24								
25								
26								
27								
28								
29								
30								

NOTES:

PROJECT:

LOCATION ID: SITE Z - Background

LOG OF BORING:

DEPTH (FEET)	SAMP. NO. SAMPLE	BLOWS/6" DRIVEN/ RECOV.	STRAT. COLUMN GRAPHICS	MATERIAL DESCRIPTION	INST. READING	CODE		NOTES
						USCS	LC	
1	X	7	6"	90'; Saprolite - SAA				0.0 ppm Ambient
2								10.8 ppm baggie H ₂ O
3								
4								
5								
6								
7								
8								
9								
100	X	12 21 55	3"	100'; Saprolite - SAA				0.0 ppm Ambient
1								43.5 ppm baggie H ₂ O
2								
3								
4								
5								
6								
7								
8								
9								
1								
2								
3								
4								
5								
6								
7								
8								
9								

NOTES:



11325 SUNRISE GOLD CIRCLE, SUITE 'E'
RANCHO CORDOVA, CA 95742
(916) 638-9892 • FAX (916) 638-9917

CHAIN OF CUSTODY RECORD

Page 1 of 1

PROJECT # DE268.29.04 PO # DE268.29.09

COLLECTED BY (Signature)

John Ratz John Ratz

REMARKS

[illegible]

RELINQUISHED BY: DATE/TIME

RECEIVED BY: DATETIME

RELINQUISHED BY: DATE/TIME

RECEIVED BY: DATE/TIME

4-3-93 / 1100 FEDERAL EXPRESS

FEDERAL EXPRESS

EXPRESS

4/6/93 15:28

LAB USE ONLY

SHIPPER NAME

AIRBILL#

OPENED BY: DATETIME

TEMP(°C)

CONDITION

REMARKS



AIR TOXICS LTD.

AN ENVIRONMENTAL ANALYTICAL LABORATORY

11325 SUNRISE GOLD CIRCLE, SUITE 'E'
RANCHO CORDOVA, CA 95742
(916) 638-9892 • FAX (916) 638-9917

CHAIN OF CUSTODY RECORD

Page 1 of 1

PROJECT # DEZ68.29.09 PO # DEZ68.29.09

COLLECTED BY (Signature) John Ratz

REMARKS Attn: Bob Freeman

FIELD SAMPLE I.D.# SAMPLING MEDIA (Tenax, Canister etc.)

DATE/TIME

ANALYSIS

VAC./PRESSURE

LAB I.D. #

01A HI-H-VLW	Summa Canister 12042	4-22-93 / 1425	T0-3 ref. to JP-4	0" Hg	
02A HI-H-MPC-12.4	" " AT 9317	4-22-93 / 1512	" "	0" Hg	
03A HI-H-MPA-6	" " 12280	4-22-93 / 1725	" "	1.0" Hg	

RELINQUISHED BY: DATE/TIME

RECEIVED BY: DATE/TIME

RELINQUISHED BY: DATE/TIME

RECEIVED BY: DATE/TIME

Chadwick 4-23-93 / 1030 Summa 4-22-93 15:00

LAB USE ONLY

SHIPPER NAME

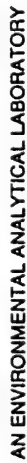
AIR BILL #

OPENED BY: DATE/TIME

TEMP(°C)

CONDITION

REMARKS



11325 SUNRISE GOLD CIRCLE, SUITE 'E'
RANCHO CORDOVA, CA 95742
(916) 638-9892 • FAX (916) 638-9917

CHAIN OF CUSTODY RECORD

Page 1 of 1

PROJECT # DE 268.29.09 PO # DE 268.29.09 COLLECTED BY (Signature) John Kitz - Ck Kelly
REMARKS Attn: Bob Freeman

FIELD SAMPLE I.D.#	SAMPLING MEDIA (Tenax, Canister etc.)	DATE/TIME	ANALYSIS	VAC./PRESSURE	LAB I.D. #
01A/10	Summa Canister	4-27-93/1055	T0-3 referenced to JP-4	1" Hg / 15 psi	
02A	"	4-27-93/1345	T0-3 referenced to JP-4	1.5" Hg / 15 psi	
03A	"	4-27-93/1508	T0-3 referenced to JP-4	2" Hg / 15 psi	
04A	"	4-27-93/1525	T0-3 referenced to JP-4	2" Hg / 15 psi	

RELINQUISHED BY: DATE/TIME	RECEIVED BY: DATE/TIME	RELINQUISHED BY: DATE/TIME	RECEIVED BY: DATE/TIME
Chas. Barker 4-27-93 1:30 PM	ATC		
			4/28/93 1:30

LAB USE ONLY

SHIPPER NAME	AIR BILL #	OPENED BY: DATE/TIME	TEMP(°C)	CONDITION

REMARKS

CHAIN OF CUSTODY RECORD

Page 1 of 1

ENGINEERING-SCIENCE, INC.

1700 BROADWAY, SUITE 900
DENVER, COLORADO 80290
303-831-8100

AFCEE BIOVENTING PILOT TESTS

Base: Hickam AFB, Hawaii

Site: Area H

ES Job No.

DE268.29.08

Sampler(s): (Signature)

John Katz
Craig S. Miller
Long S. Miller

Date	Time	Sample Description	Lab I.D.	No. of Conts.
3-22-93	1330	HI-H-VW-18		2

Preservative		Analysis Required	
NONE	HOLD	AT 40	NONE
SW 9045 (PH)	<input checked="" type="checkbox"/>	A 403 (ALKA)	<input checked="" type="checkbox"/>
SW 7380 (IRON)	<input checked="" type="checkbox"/>	SW 846 (MOIST)	<input checked="" type="checkbox"/>
SW 8020 (BTEX)	<input checked="" type="checkbox"/>	E 418.1 (TRPH)	<input checked="" type="checkbox"/>
E 3512 (TKN)	<input checked="" type="checkbox"/>	E 365.3 (PHOS)	<input checked="" type="checkbox"/>
E 3512 (TKN)	<input checked="" type="checkbox"/>	UCM	<input checked="" type="checkbox"/>

Relinquished by: (Signature)

Craig S. Miller

Date / Time

3/22/93 16:40

Relinquished by: (Signature)

Long S. Miller

Date / Time

3/22/93 16:40

Date / Time

3/22/93 0900

Date / Time

3/22/93 0900

Ship To:

ENGINEERING-SCIENCE LABORATORY
600 Bancroft Way
Berkeley, CA 94710

Attn: Tom Paulson
(510) 841-7353

Sample Type

G C

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G C

Remarks: Please call if any questions,

John Katz (808) 944-8009

Gail Saxton (303) 831-8100

G - Grab Sample, G - Composite Sample

ENGINEERING-SCIENCE, INC.

1700 Broadway, Suite 900 • Denver, Colorado

(303) 831-8100

Distribution: Original Accompanies Shipment. Copies to: Coordinator Field Files

Federal Express Number:

Albini Number: 829 869 791

CCRS01K

CHAIN OF CUSTODY RECORD FOR WATER SAMPLES

[illegible]

CHAIN OF CUSTODY RECORD

[illegible]

CLAIM OF CUSTODY RECORD FOR WATER SAMPLES

[illegible]

CHAIN OF CUSTODY RECORD

AFCEE BIOVENTING PILOT TESTS

ENGINEERING-SCIENCE, INC.
1700 BROADWAY, SUITE 900
DENVER, COLORADO 80290
303-831-8100

Base: *Hickam AFB, HI*

Site: *ARE-10 H-3K*

ES Job No.

DE268. 2 9 .08

Sampler(s): (Signature)

John Ratz *Chris Miller*

John Ratz *Chris Miller*

Lab I.D.

Sample Description

No. of Conts.

Date	Time	Sample Description	Lab I.D.	No. of Conts.
3-24-93	0750	<i>HE-14-MPC-5</i>		1
3-24-93	1320	<i>HE-K-VW-6.5</i>		2
3-24-93	1445	<i>HE-K-MPA-5.5</i>		2

Ship To:

ENGINEERING-SCIENCE LABORATORY
600 Bancroft Way
Berkeley, CA 94710

Attn: Tom Paulson
(510) 841-7353

Preservative
NONE
AT 4C
HOLD

Analysis Required
SW 9045 (PH)
A 403 (ALKA)
SW 7380 (IRON)
SW 846 (MOIST)
SW 8020 (BTEX)
E 418.1 (TRPH)
E 3512 (TKN)
E 3653 (PHOS)
UCM (CLASS)

Remarks

Matrix

Sample Type

SOIL
SOIL
SOIL
SOIL
SOIL
SOIL
SOIL
SOIL
SOIL
SOIL
SOIL
SOIL
SOIL
SOIL
SOIL
SOIL
SOIL
SOIL
SOIL

TKN analysis only.

Received for Laboratory by: (Signature)

Date / Time

3/24/93 16:30

Relinquished by: (Signature)

Relinquished by: (Signature)

Received for Laboratory by: (Signature)

Date / Time

Date / Time

3/25/93 0900

Date / Time

Remarks: If any questions please call:
JANUARY (802) 944-8009
SALES (303) 831-8100
ATTENTION: Tom Paulson

Q-Grab Sample, C-Composite Sample

ENGINEERING-SCIENCE, INC.

1700 Broadway, Suite 900 • Denver, Colorado
(303) 831-8100

Distribution: Original Accompanies Shipment. Copies to: Coordinator Field Files

Federal Express Number: *911253757*

Airbill Number:

ENGINEERING-SCIENCE

CHAIN OF CUSTODY RECORD FOR WATER SAMPLES

JOB NO.		PROJECT NAME/LOCATION		PRESERVATIVES REQUIRED												ANALYSES REQUIRED												REMARKS
4927		4927																										TO: SEQUOIA LAB.
FIELD CONTACT:																												
SAMPLER NAMES & SIGNATURES																												
DATE	TIME	FIELD SAMPLE IDENTIFIER																										
4/23	0750	HI-HMPC-5 (4927.01A)																										(01)
	1320	HI-K-VW-6.5 (4927.02B)																										(02)
	1445	HI-K-MPA-5.5 (4927.03B)																										(03)
W.O. # 93-03-C74																												
Relinquished By <i>[Signature]</i>																												
3/26/43 1230																												
FIELD CUSTODY RELINQUISHED BY:																												DATE: 3/25/93 TIME: 0945
RECEIVED VIA:																												ON RECEIPT: CUSTODY DEALER? ; TEMP: °C
RECEIVED FOR LABORATORY BY: <i>[Signature]</i>																												DATE: 3/26/93 TIME: 1445

CCRSX

CHAIN OF CUSTODY RECORD FOR WATER SAMPLES

70: SEQUOIA LAB.

**CHAIN-OF-CUSTODY RECORD
Analytical Request**

Client **PACE - NOVATO (AFCEE - HICKAM AFB)**

Report To: **Ron Chew**

Pace Client No.

Address **11 Digital Dr.**

Bill To:

Pace Project Manager

Novato CA 94949

P.O. # / Billing Reference

Pace Project No. **47025 S11**

Phone **(415) 883-6100**

Project Name / No.

*Requested Due Date: **6/8/93**

Sampled By (PRINT):

3/25/93

Sampler Signature

Date Sampled

ITEM NO. SAMPLE DESCRIPTION TIME MATRIX PACE NO.

1	HI - K - MPB - 5.5	0830	Soil	18941.1
2				
3				
4				
5				
6				
7				
8				

NO. OF CONTAINERS

PRESERVATIVES
UNPRESERVED
H₂SO₄
HNO₃
VOA

ANALYSES REQUEST
TRPH (E 418.1)

REMARKS

Crack the Corral
& Test for TRPH.

COOLER NOS.	BAILERS	SHIPMENT METHOD OUT / DATE	RETURNED / DATE	ITEM NUMBER	RELINQUISHED BY / AFFILIATION	ACCEPTED BY / AFFILIATION	DATE	TIME
					Theresa Hoover yps	PACE	5/25/90	
					GN For yps	PACE	5-16 10:15	

Additional Comments

Attn: Melanie Concepcion.

Red @ 5.8

**GN CUSTODY SENT
IN DET**

Page 1 of 1

CCNSOIL

CONFIDENTIAL

Sequoia *hab*

- Sub-Unit -

INDEX

9364 107-61

4943-18

TKN

1x

Retinguished By: Jim Vannink
4/1/93 1225

DATE: 3 130 9/3 TIME: 0952

ON RECEIPT: CUSTODY DEALER _____; TEMP: _____ °C

TRINITY

DATE: 6/1/93 TIME: 10:05

16 Surfer

CHAIN OF CUSTODY RECORD

ENGINEERING-SCIENCE, INC. 1700 BROADWAY, SUITE 900 DENVER, COLORADO 80290 303-831-8100		AFCEE BIOVENTING PILOT TESTS Base: <i>Altona AFB, HI</i> Site: <i>2</i>		ENGINEERING-SCIENCE LABORATORY 600 Bancroft Way Berkeley, CA 94710		Ship To:
ES Job No. DE268. <i>2</i> <i>9</i> .08		Sampler(s): (Signature) <i>John Ratz</i> <i>John Ratz</i>		Attn: Tom Paulson (510) 841-7353		
Date <i>3-30-93</i>		Time <i>1314</i>		Sample Description <i>HE-2-VW-29.5</i>		Remarks <i>Preserved on ice.</i>
Date <i>3-30-93</i>		Time <i>1314</i>		Sample Description <i>HE-2-VW-29.5</i>		
Relinquished by: (Signature) <i>John Ratz</i>		Date / Time <i>3-30-93</i> / <i>1600</i>		Received for Laboratory by: (Signature) <i>John Ratz</i>		Date / Time <i>3/31/93</i> / <i>0900</i>
Relinquished by: (Signature)		Date / Time		Received for Laboratory by: (Signature)		
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ENGINEERING-SCIENCE

RECEIVED FOR LABORATORY BY: Eric Vennart DATE: 4/1/93 TIME: 10:15 Monday

CCN50

CONFIDENTIAL

DATE: 4/5/93 TIME: 1410

ES JOB NO.	PROJECT NAME/LOCATION
	4974

FIELD CONTACT:	
SAMPLER NAMES & SIGNATURES	FIELD SAMPLE IDENTIFIER
	HZ-2-MPB-50(4974.OIB)

DATE	TIME
4/12/83	1138

PRESERVATIVES REQUIRED	ANALYSES REQUIRED
	E 3512 (TKN) X E 965.3 (PHOS) X UICM (CLASS) X
	9304850 . ON

REMARKS
REPORT TO: TOM PAULSON NORM TAY.

TG:
SEQUOIA LAB.

SHIPPED VIA:	AIRBILL #	ON RECEIPT: CUSTODY BEARS?	TEMP: _____ °C
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DATE: 4/16/93 TIME: 11:5-

CHAIN OF CUSTODY RECORD

[illegible]

[illegible]